Interconnection Technical Standards Review Group (TSRG)
Duke Energy Carolinas/Progress
Meeting Agenda
April 28, 2020

In-person meeting converted to web meeting to follow distancing guidelines for COVID-19

9:00	Safety & Introductions – Wes Davis, Duke
9:05	Periodic self-inspection plan update – Kevin Chen, Duke
9:50	Volt-VAR study results and IEEE 1547 implementation plan status – Anthony Williams, Duke
10:50	Break
11:00	Updates on the DER Enterprise Standards Project – Anthony Williams, Duke
11:20	Additional discussion on topics, if needed
11:50	Wrap up & next meeting date – Wes Davis, Duke (Recommend July 21, 22)
12:00	ADJOURN

Interconnection Technical Standards Review Group (TSRG)
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Minutes and Attendance
April 28, 2020

I. Opening

This is a regular meeting called to order at 9 AM in Raleigh, NC

Meeting facilitator: Anthony Williams

Minutes: Raven Bowden

II. Record of Attendance

Member Attendance

Name	Affiliation	Attendance
Kevin Chen	Duke Energy	Present
Jeff Daugherty	Duke Energy	Present
Wes Davis	Duke Energy	Present
Jonathan DeMay	Duke Energy	Present
Raven Bowden	Pike Engineering	Present
Huimin Li	Duke Energy	Present
Orvane Piper	Duke Energy	Present
Bill Quaintance	Duke Energy	Present
Jonathon Rhyne	Duke Energy	Present
Anthony Williams	Duke Energy	Present
Stephen Barkaszi	Duke Energy	Absent
Paul Brucke	NCSEA, Sustainable Energy Assoc	Present
Jon Burke	GreenGo Energy	Absent
James Wolf	Yes Solar Solutions	Absent
Moath Dardas	Strata Solar	Present
Jason Epstein	Southern Current	Absent
John Gajda	Strata Solar	Present
Sean Grier	Duke Energy	Absent

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Name	**Affiliation**	**Attendance**
Scott Griffith	Duke Energy	Absent
Chuck Ladd	Ecoplexus	Present
Bruce Magruder	Keytech Engineering	Present
Luke O'Dea	Cypress Creek	Present
Chris Sandifer	SCSBA, Solar Business Alliance	Present
Reigh Walling	NCCEBA, Clean Energy Bus Alliance	Absent
Luke Rogers	Birdseye Renewable Energy	Absent
Dawn Hipp	SC Office of Regulatory Staff	Absent
Sarah Johnson	SC Office of Regulatory Staff	Absent
Robert Lawyer	SC Office of Regulatory Staff	Present
Jay Lucas	NC Public Staff	Absent
James McLawhorn	NC Public Staff	Absent
Dustin Metz	NC Public Staff	Present
Tommy Williamson	NC Public Staff	Absent
Todd Rouse	Cypress Creek	Absent
Max Semerau	Strata Solar	Absent
Mike Wallace	Ecoplexus	Absent

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Guest Attendance

Name	**Affiliation**	**Attendance**
Tim Robeson	Duke Energy	Present
Jonathon Rhyne	Duke Energy	Present
Staci Haggis	Advanced Energy	Present
Shawn Fitzpatrick	Advanced Energy	Present
Kelsy Green	Advanced Energy	Present
Nate Finucane	Duke Energy	Present
Bruce Fowler	BAM Energy	Present
Cyrus Dastur	Advanced Energy	Present
Peter Hoffman	Duke Energy	Present

III. **Current agenda items and discussion**

1) The published agenda was emailed before the meeting.
2) PRESENTATION – Periodic self-inspection plan update – Kevin Chen, Duke
   A) Presentation provided with minutes.
   B) Industry Question: Overhead structure clearances per Duke standards (not NESC) may be a challenge to developers because some of the sites were installed prior to issuing the Duke standards. They may be built to the NESC. Another area of concern is just the number of codes listed.
      a. Duke answer: Agreed, there could be some installs that predate the current standards. Please send that comment in writing and Duke will review and address that situation.
   C) Industry Question: What should be used as a guide for the expected settings for sites, such as the settings for inverter protection?
      a. Duke answer: The intention of the self-inspection is that Duke will provide the expected settings for the site. The customer shall verify and check whether the site meets the expected items.
3) PRESENTATION – Volt-VAR study results and IEEE 1547 implementation plan status – Anthony Williams, Duke
   A) Presentation provided with minutes.
   B) Industry Question: Are the three items you identified being evaluated as ancillary services and should that discussion be included as a TSRG topic?

(noting the NCUC recent Avoided Cost Order and trying to quantify Ancillary services in future Avoided Cost hearings)?

   a. Duke answer: The Duke TSRG leadership is not aware of what is included in the order concerning ancillary services. Duke will find out more about the order, what services are included, and what is being done by Duke to address the order and then consider role for TSRG. A benefit of performing studies like the Volt-VAR is to take a first step towards knowing what the impact of that function. That could be input to the ancillary service discussion. As a future topic TSRG could discuss the role ancillary services has in the interconnection procedure.

C) **ACTION ITEM:** Duke will find out more about the ongoing activities to address the order for ancillary services and hold a discussion in the TSRG concerning the contribution of the TSRG.

D) Industry Question: Concerning the Volt-VAR pilots; is Duke considering existing and to be built sites for pilots?

   a. Duke answer: The details of the pilots have not been detailed much at this point given there are still several other issues to work through. The first thought would be to use existing sites although there may need to be some adjustment to the control setpoints given that there should be less need for VAR control at an existing site because it was designed to operate within limits.

E) Industry comment: What is Duke Energy's high-level takeaway from this Volt-VAR study?

   a. Duke Energy: First, Duke energy was pleased that a controller setting was found that was viable without needing to be customized for every DER. Secondly, Duke energy was not expecting to see high reactive power being absorbed at peak. Duke is still investigating the consequences of this and control alternatives to minimize it. Lastly, Duke demonstrated how the response charts were useful to understand the impact on the feeder with active and reactive power injections.

4) PRESENTATION – Updates on the T-D Interface agreement - DER Enterprise Project – Anthony Williams, Duke

   A) Presentation provided with minutes.

   B) Industry comment: Duke Energy is looking internally to perform all this analysis. Will Duke also consider using outside resources?

      a. Duke Energy: The T-D interface team is doing all the work internally and the work they are focused on now is the proof of the concept and the development of the methodology. At this point, there would be nothing for anyone outside Duke to follow, because there is no final method. In the future, the expectation is that the team will have a methodology that is practical to implement as part of the interconnection process, but that method is unknown for now.

C) Industry Question: So, the policy remains that DEP and DEC have different opinions on whether to implement DTT?
   a. Duke answer: Correct. Duke is still working on DTT and other protection requirements. There has been no policy changes. A main goal of the work is to develop robust protection schemes to meet all the design criteria. DTT is just one piece that may fit into the overall work.

D) Industry Question: Would the Duke team consider allowing yet to be built sites that currently require DTT to move to this new design if it removes the need for DTT at that site?
   a. Duke answer: Duke Energy will have to discuss with the team and evaluate once Duke knows the final solution.

E) Industry Question: Would the IEEE-1547 Ride Through consideration be part of this project?
   a. Duke answer: This is primarily a protection study. However, they are looking at ride through considerations. Duke expects that the abnormal categories will be apparent once the final trip setpoints are determined.

IV. **Next Meeting Date**

The group tentatively selected July 21, 2020 for the next meeting.

V. **Closing**

The meeting adjourned at 11:28 AM.

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VI. **Attachments**

1) Agenda, “TSRG Agenda 2020_0428, Rev 0.pdf”
2) Presentations:
    a. Enterprise DER Protection Update, “Enterprise DER Protection Update 2020 0425.pdf”
    b. Self-Inspection Manual, “Self-inspection Instruction Manual_draft_2020-04-28.pdf”
    c. Self-Inspection Plan, “Self-inspection plan_TSRG_04282020_v2.pdf”
    d. Self-Inspection Process, “Self-inspection process_draft_2020-04-28.pdf”
    e. Self-Inspection Report Template, “Self-Inspection Report Template_draft_2020-04-15.docx”
    f. TSRG Implement 1547 Update, “TSRG Implement 1547 Update, April 28 2020, Rev 1.pdf”
    g. TSRG Volt-VAR Update, “TSRG Volt-VAR Update, April 28 2020, Rev 1.pdf”

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Action Items

Below are the action items from the TSRG meetings and their status.

Meeting	Item Number	Action Item	Summary	Status Summary
Apr-2018	1	Provide overall description of SIS process	Action Item description is too broad and requires scope clarification in order to take action	Hold
Apr-2018	2	Update TSRG on current and future work with Salesforce and PowerClerk	Agenda item for July 19	Complete
Apr-2018	3	Verify there is a feedback process to share owner issues and concerns about the process with Duke	An inspection and commissioning subcommittee was formed and part of the scope of this group is to address issues such as these. Therefore, the subcommittee will be the main forum for feedback. Update is agenda item for July 19.	Complete
Apr-2018	4	Identify various “operating requirements” and where best to document them	Action Item description is too broad and requires scope clarification in order to take action	Hold
Apr-2018	5	Provide status of effort to provide study reports to Requestors	This group within the company is being reorganized. The reporting is a known issue: when to communicate, what to communicate, how to communicate. There are efforts in the works to improve the situation, but it may worthwhile for TSRG members to recommend specific content.	Complete

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Action Items

Meeting	Item Number	Action Item	Summary	Status Summary
Apr-2018	6	Provide typical DEP station and line regulator bandwidth settings	It is difficult to say that there are typical settings for voltage control devices like line regulators, station feeder regulators, station bus regulators, and station transformer tap changers. These devices are applied at different locations within the power system, which gives each type of device a different span of control. They also are configured to manage a variety of load densities and circuit lengths. Some applications use voltage drop compensation and those have a very different bandcenter setpoint than a unit that does not use compensation. A common bandwidth setting for DEC is 2V, but some zones have been designed with a 3 V bandwidth. With the DSDR requirements, most DEP bandwidths are 2V for line regulators and 1V for station regulators.	Complete
Apr-2018	7	Clarify how mitigating solutions are considered and applied	Action Item description is too broad and requires scope clarification in order to take action. This item is also addressed by item 14.	Complete

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Action Items

Meeting	Item Number	Action Item	Summary	Status Summary
Apr-2018	8	DMS update on DER related functionality in ADMS	The current DMS deployment does not have integration of DERs into the advanced functions. In the future, this is a requirement for DSDR (optimized Peak reduction) in DEP. The DEP DMS is scheduled to be in service April 2019. Bear in mind that these project dates are movable based on changing priorities and constraints. As far as the following capabilities: • adjusting nominal voltage setpoint as a mitigation for negative voltage impacts, and • adjusting volt-var control to allow for alternative voltage control methods utilizing inverter capabilities Those capabilities are not included in the near term DMS implementations. These features add a great deal of complexity and are scheduled towards the end of the ADMS consolidation period and beyond. This schedule was based on balancing many priorities, constraints and commitments among many Duke Energy departments and functional groups. The adjustment of nominal voltage setpoint down as a mitigation for negative voltage impacts will be a part of the Modern Voltage Management Strategy, but that schedule is not in place yet.	Complete
Apr-2018	9	Provide information about the original need for RVC criteria	Provided 2 documents prior to the July meeting. One is a study from NC State University and one from Xcel Energy.	Complete
Apr-2018	10	Clarify inverter short circuit modeling methods	Studies use the short circuit capability from the submitted inverter specification sheet. Generally the Cyme Electronically Coupled Generator model is used with the specified fault contribution.	Complete
Apr-2018	11	Communicate information about material changes of transformer and inverter data	Provided document with march meeting minutes, "Dist-DER_Engr_and_Study_stds_clarifications-rev1-0.docx"	Complete

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Action Items

Meeting	Item Number	Action Item	Summary	Status Summary
Jul-2018	12	Post the information from July site inspections seminar	A Technical Training will be added to the webpage and contain the July training presentation and the Distribution Standards Reference Guide. Will post by 10/23/18.	Complete
Jul-2018	13	Process for smaller project feedback on the study process	All projects that are less than 20KW would need to inquire about the project's status through the Renewable Service Center. Their email address for inquiries is Customerownedgeneration@duke-energy.com. For projects greater than 20KW that are still within the study phase and haven't been released to an account manager, those projects can be directed to DERContracts@duke-energy.com. This is the email for OPSCAS team that handles project status inquiries before they are handed off to an account manager.	Complete
Jul-2018	14	Summarize the mitigation options along with the associated policies	Agenda item for October meeting	Complete
Jul-2018	15	Provide a summary of the Modern Voltage Management Strategy	This Strategy is not complete enough to share at this time. This can be reviewed with the TSRG at a future meeting.	Hold

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Action Items

Meeting	Item Number	Action Item	Summary	Status Summary
Jul-2018	16	Provide more details on operational limitations imposed by DSDR	A summary of the DSDR operational limitations will be provided during the October meeting.	Complete
Oct-2018	17	Method of selecting the study voltage for interconnection studies	Agenda item for Jan TSRG meeting	Complete
Oct-2018	18	Provide the level of solar above which DTT is considered	Agenda item for Jan TSRG meeting	Complete
Oct-2018	19	Status of Risk of Islanding Studies	Agenda item for Jan TSRG meeting	Complete
Jan-2019	20	Provide information from the EPRI DTT surveys	The EPRI report is not complete and will not be public. A total of approximately 50 utilities are represented in the survey. The load to generation ratio is a very common screening criterion. There is no consensus screening practice. Radio and fiber are the most commonly used for communication. A large portion of the utilities are currently reviewing DTT policies.	Complete
Jan-2019	21	Communicate bases for DTT on dedicated feeders to a distribution station	DTT is not required for distribution DER interconnections that have a dedicated feeder from the substation. If there was a need to isolate the generator, it would be tripped at the dedicated circuit breaker. A review of the interconnection requests showed a few interconnections that specified a dedicated feeder, but none with DTT required.	Complete

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Action Items

Meeting	Item Number	Action Item	Summary	Status Summary
Jan-2019	22	Verify if 900 MHz radio is acceptable for DTT	There have been implementations of 900 MHz radio systems at various times on the Duke system. The Duke experience, and that of some co-ops, is these systems do not have high reliability and are susceptible to a variety of issues. Nevertheless, this communication option is considered as part of the enterprise-wide DTT policy review.	Complete
Jan-2019	23	Attempt to reconstruct the original basis for the 3% limit in the FCR	Duke noted at the last TSRG meeting the 3% limit has been in place at least a decade. We did not look any further back than that. Originally, the limit was 2% for transmission only and then was later increased to 3% and included distribution. The 3% is based on experience from actual events and considers that not every operating condition and customer sensitivity can be precisely anticipated and studied in advance.	Complete
Jan-2019	24	Provide more description on how the historical voltages are selected by the tools and software	Agenda item for May TSRG meeting	Complete
Jan-2019	25	Provide an overview of the distribution planning process	General scope like this is usually too broad to address effectively at TSRG. Duke prefers to focus on a specific issue that the industry prioritizes, like the voltage selection topic on the agenda for May.	Hold
May-2019	26	Duke will ask Protection if leased fiber is an option that is not currently communicated for distribution	Because of the poor reliability, troubleshooting and O&M issues, continued degradation of 3rd party equipment and service, along with the shorter distances between the station and the site, Duke does not allow the 3rd party fiber for distribution.	Complete
May-2019	27	Duke will provide a description of what is done for station-level DTT	The combined undervoltage and overvoltage (27/59) protection Duke installs is for the same purpose as 3V0. This protection was used prior to DER installations and one reason it was chosen was that it uses one less CVT than 3V0.	Complete

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Meeting	Item Number	Action Item	Summary	Status Summary
Sept-2019	28	Duke will publish the requirements and clarify the transition period between the existing and revised requirements for sequential switching.	Agenda item for Jan TSRG meeting	Complete
January – 2020	29	Duke will create a rough draft of the self-inspection manual before the next TSRG meeting and provide for discussion at the meeting	Email sent by Kevin Chen on 4/15/20	Closed
January-2020	30	Duke to discuss membership at the next meeting.	Postponed for the April meeting (meeting shortened due to COVID-19)	Hold
January – 2020	31	Email EPRI fast track and supplemental review report and Duke's response to the report to the TSRG.	Email sent by Anthony Williams on 4/3/20	Closed

Attachment D

Update and Discussion: Action Plan to Implement 1547-2018 TSRG Meeting

Anthony C Williams, P.E.
Principal Engineer

DER Technical Standards
April 28, 2020

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Agenda

- Setting priorities
- Selected order
- Next steps
- Discussion

Ground Rules

- All Stakeholder Group meetings, webinars and information exchange are designed solely to provide an open forum or means for the expression of various points of view in compliance with **antitrust laws**.
- Under no circumstances shall Stakeholder Group activities be used as a means for competing companies to reach any understanding, expressed or implied, which tends to **restrict competition**, or in any way, to impair the ability of participating members to exercise independent business judgment regarding matters affecting competition or regulatory positions.
- Proprietary information shall not be disclosed by any participant during any group meetings. In addition, no information of a secret or **proprietary** nature shall be made available to Stakeholder Group members.
- All proprietary information which may nonetheless be publicly disclosed by any participant during any group meeting shall be deemed to have been disclosed on a **non-confidential** basis, without any restrictions on use by anyone, except that no valid copyright or patent right shall be deemed to have been waived by such disclosure.

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Logistics

- Clarifying questions will be answered during the presentation and stakeholder discussions at the end of the presentation
- Written feedback and comments will be solicited using comment form
  - Note questions then lets discuss – don't really want all the questions sent in that are mainly just for clarification – this takes a lot of time to address that could be spent on the comments and recommendations
  - It would be helpful to provide more Comment and Proposed Change details :

Stakeholder Name	Page Number	Paragraph Number	Comment	Proposed Change
example Question format	3	2	Why is winter data excluded?	None
example Comment format	7	4	Agree with the hours of study.	None
example Comment format	7	4	'the largest' is not clear	Replace 'the largest' with 'the maximum of the three phase currents"
example Recommendation format	10	3	The types of faults is too limited. Include single line to ground faults.	Include SLG faults

  - Being more specific makes the point, or main concerns, of the comment more apparent and allows a more direct response.
- Comments will be taken during the discussion and the form will be distributed after the meeting
- Share the feedback form using email: Duke-IEEE1547@duke-energy.com for stakeholders to provide their written feedback

General Guidance for Priorities

- Consider IEEE 1547 functions that could potentially increase the amount of DER capacity that could increase interconnection capability
  - 4.6.2 Capability to limit active power
  - 5.3 Voltage and reactive power control
  - 5.4 Voltage and active power control
- Consider IEEE 1547 sections that impact grid support
  - Mainly based on guidance from documents such as the NERC Reliability Guideline: Bulk Power System Reliability Perspectives on the Adoption of IEEE 1547-2018
- Stakeholder comments
- Implementation plan reviews from other utilities
- All these factors impacted the priority order

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Priority Setting: 1st and 2nd Priority Example

Selected Order:

1. Topical Priority
2. Member Count
3. Member Average
4. Duke & NERC Average

IEEE 1547 Section	IEEE 1547-2018 Topic	TSRG Selected Order	Duke Order	NERC Relib Guide	Member 1	Member 2	Member 3	Member Count	Member Average	Count	Total	Average
5.2	**Reactive power capability of the DER**	1	1		1	3	3.1	3	2.4	4	8.1	2.0
5.3	**Voltage and reactive power control**	1	1		1	3	3.1	3	2.4	4	8.1	2.0
5.4.2	**Voltage-active power control**	1	1		1	3	3.1	3	2.4	4	8.1	2.0
7.4	Limitation of overvoltage contribution	1	7		1	2	4.1	3	2.4	4	14.1	3.5
7.2.3	Power Quality, Flicker	1	7		1	2	4.1	3	2.4	4	14.1	3.5
7.2.2	Power Quality, Rapid voltage change (RVC)	1	7		1	2	1	3	1.3	4	11.0	2.8
6.4.1	Mandatory voltage tripping requirements (OV/UV)	2	4	1	1	4	1	3	2.0	5	11.0	2.2
6.5.1	Mandatory frequency tripping requirements (OF/UF)	2	4	1	5	4	3	3	4.0	5	17.0	3.4
6.4.2	Voltage disturbance ride-through requirements	2	4	1	1	[illegible]	2	3	2.3	5	12.0	2.4
6.5.2	Frequency disturbance ride-through requirements	2	4	1	1	[illegible]	4	3	3.0	5	14.0	2.8
6.5.2.7	Frequency-droop (frequency-power) capability	2	7	1	1	[illegible]	5.1	3	3.4	5	18.1	3.6
6.5.2.6	Voltage phase angle changes ride-through	2	6	1	1	[illegible]	5.1	3	3.4	5	17.1	3.4

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Priority List Excerpt

TSRG Priority Order (Duke ID)	IEEE 1547 Section	IEEE 1547-2018 Topic	Technical Position Summary	Interoperability Summary	Test and Verification Summary
1 (DUK-01)	5.2	Reactive power capability of the DER	Category B 35° C ambient or higher at rated voltage	No Reqmt	Eval + Comm Test
1 (DUK-02)	5.3	Voltage and reactive power control	Study in progress	Yes	Eval + Comm Test
1 (DUK-03)	5.4.2	Voltage-active power control	Study in progress	Yes	Eval + Comm Test
1 (DUK-04)	7.4	Limitation of overvoltage contribution	Pending. Likely requires more industry experience or analysis to address this issue	TBD	Eval + Comm Test
1 (DUK-05)	7.2.3	Power Quality, Flicker	Continue existing criteria and policy	No Reqmt	Eval + Comm Test
1 (DUK-06)	7.2.2	Power Quality, Rapid voltage change (RVC)	Continue existing criteria and policy	TBD	Eval + Comm Test

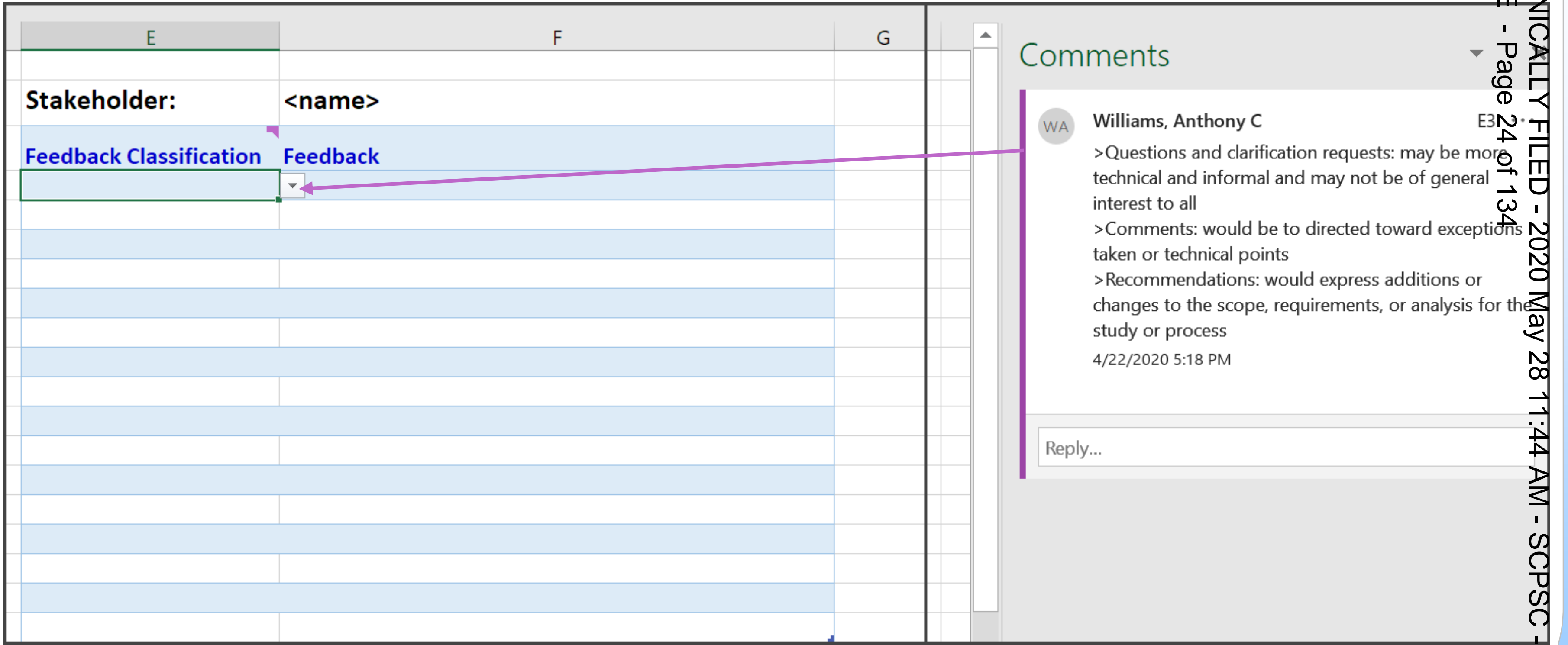
- Three summary columns on the right
- Provide general overview
- Refer to specific sections of the report for the details on that part of the Standard

Priority Groups 1 – 5 Overview

1st	• Reactive power and voltage control • Power quality
2nd	• Voltage tripping and ride through • Frequency tripping and ride through
3rd	• Most important sections of Section 4, General Tech Specs
4th	• Most commonly applied sections of Section 4, General Tech Specs
5th	• Remaining sections of Section 4, General Tech Specs

- Confirmation of the priority order
- Continue pursuing
  - Section 5 topics concerning – reactive power and voltage control
  - Section 6 O/UV and O/UF trip settings and ride through requirements
  - 3rd priority: most important general interconnection specifications and requirements
- More discussion or investigation of
  - 7.4 Limitation of overvoltage contribution
    - Seems to need more industry experience and analysis
    - Recommend moving this topic to 5th priority group
- Stage in 4th and 5th priority items after completing 3rd priority

Stakeholder Feedback Form



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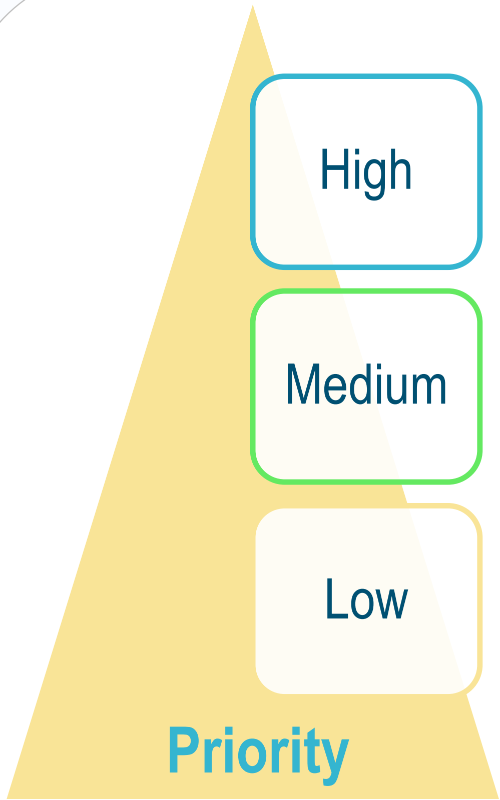
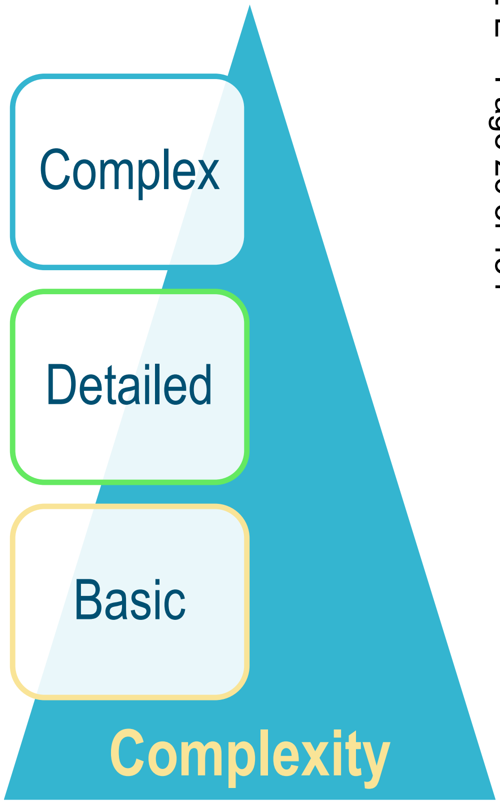
Priority and Complexity



1. Functions that enable higher penetrations of DER
2. Rank topics based on stakeholder preference
3. Note that there will be a need to spread the more complex functions over time



Interconnection Related Functions

- Past TSRG input -- Functions that enable higher penetrations of DER
- The following functions in 1547 improve the capability of DER to interconnect:
  - 5.2 Reactive power capability of the DER
  - 5.3 Voltage and reactive power control
    - 5.3.2 Constant power factor mode
    - 5.3.3 Voltage-reactive power mode
    - 5.3.4 Active power-reactive power mode
    - 5.3.5 Constant reactive power mode
  - 5.4 Voltage and active power control
    - 5.4.2 Voltage-active power mode
  - 4.6.2 Capability to limit active power

Interconnection Function Status

- Active evaluations
  - Starting with 5.3 Voltage and reactive power control
    - By necessity then, 5.2 Reactive power capability of the DER
  - Secondary focus on 5.4 Voltage and active power control
- Future evaluation
  - 4.6.2 Capability to limit active power
    - In a way, done now by restricting kW at SIS
    - Performing this during real time operations is complex
      - Implementation would need considerable investigation
- Three of these four more important functions are in progress

Discussion

- Are the proper IEEE 1547-2018 functions or requirements?
- Is the proposed order the proper order?
- By what process should the remaining items be prioritized or ordered, the poll?
- What should the development and implementation schedule look like?
- Is the TSRG the proper stakeholder membership

- Is it right that Interoperability and Communication be established early on to facilitate the other functions, data, and monitoring?
- Is it right that Test and Verification requirements be developed incrementally as the function and requirements are implemented?

SELF-INSPECTION REPORT

FACILITY NAME

AC Capacity

Street Address

City, State, Zip Code

Authored By:

Name

Report Date

Insert PE licensing language, as appropriate

Attachment E

PE

Seal

Summary

Table of Contents

1. DER AS-BUILT INSTALLATION

1.1. Agreement with Utility Documentation

☐ Provide the expected and as-built installation information in the table below. Expected information is based on the documentation provided by Duke Energy prior to the inspection.

Table 1. Expected vs. As-Built Installation; Differing Information in Red

	Expected by Duke Energy	**As-Built Installation**
Site Name		
Site Address		
IPP Number		
AC Output		
Interconnection Voltage		
Commenced Operation Date		
Transformers (Quantity, Size, Primary/Secondary Grounding)		
Inverters (Quantity, Manufacturer, Model)		
Last Duke Energy Commissioning Test Date		

Does the major equipment at the DER facility agree with the documentation provided by Duke Energy prior to the inspection?

☐ Yes ☐ No

If the answer to the above is No, has an updated SLD been submitted to the Duke Energy account manager?

☐ Yes ☐ No

1.2. Inverter Information

Are the inverters listed by a Nationally Recognized Testing Laboratory (NRTL) to UL 1741?

☐ Yes ☐ No

What NRTL listed the inverters?

☐ Provide photos of one nameplate for each model inverter

Note: Verify all text is legible, including the NRTL certification. It may be necessary to take multiple pictures of sections of the same nameplate to provide legible pictures. If multiple sections are required, a full picture of the entire nameplate shall also be included as well. Often, flash photography makes the label illegible.

☐ Provide inverter data in electronic format using the Excel report template.

1.3. Transformer Information

What is the primary (high voltage) winding configuration?

☐ Delta ☐ Grounded Wye ☐ Ungrounded Wye

What is the secondary (low voltage) winding configuration?

☐ Delta ☐ Grounded Wye ☐ Ungrounded Wye

What is the tertiary (low voltage) winding configuration?

☐ No tertiary ☐ Delta ☐ Grounded Wye ☐ Ungrounded Wye

☐ Provide photos of one nameplate for each model transformer

Note: Verify all text is legible, including sections with imprinted or stamped numbers or text. It may be necessary to take multiple pictures of sections of the same nameplate to provide legible pictures. If multiple sections are required, a full picture of the entire nameplate shall also be included as well. Often, flash photography makes the label illegible.

☐ Provide transformer data in electronic format using the Excel report template.

2. INTERCONNECTION EQUIPMENT SETTINGS

2.1. Inverters

☐ Provide the expected, as-found and as-left inverter settings in the table below.

Table 2. Expected, As-Found and As-Left Inverter Settings; Incorrect Settings in Red

Parameter	Expected Settings (per utility documentation)		As-Found Settings		As-Left Settings	
	Value	Delay (seconds)	Value	Delay (seconds)	Value	Delay (seconds)
Under Voltage 1						
Under Voltage 2						
Over Voltage 1						
Over Voltage 2						
Under Frequency 1						
Under Frequency 2						
Over Frequency 1						
Over Frequency 2						
Power Factor						
Grid Reconnect Timer						
Maximum AC Power						
Advanced Grid Functions (e.g. LVRT, HVRT, volt-var)						

Are the as-left inverter settings in compliance with the DER facility's Interconnection Agreement?

☐ Yes ☐ No

☐ Enter the inverter serial, software and firmware numbers in the table below.

Table 3. Inverter Serial Numbers and Firmware Versions

Inverter Designation	Serial Number	Software/Firmware Version Numbers
Inverter 1		
Inverter 2		
Inverter 3		
Inverter 4		
Inverter 5		
Inverter 6		

☐ Provide a full set of inverter settings for each inverter. Settings could be in the form of an export from the inverter, screenshots, photos of the inverter HMI, etc.

In what format are the inverter settings provided?

2.2. Additional Interconnection Protection Equipment

Does the DER facility have any additional interconnection protection equipment beyond the inverters, such as a facility-owned recloser or plant controller?

☐ Yes ☐ No

Type of interconnection protection equipment:

☐ Recloser

☐ Other:

☐ Provide the settings for each additional interconnection protection equipment in the table below.

Table 4. DER Facility-Owned Protection Settings

Parameter	Settings	
	Value	**Delay (seconds)**
Under Voltage 1		
Under Voltage 2		
Over Voltage 1		
Over Voltage 2		
Under Frequency 1		
Over Frequency 1		
Grid reconnect timer	-	

3. ACCESS TO DUKE ENERGY INTERCONNECTION FACILITIES

Is the as-left condition of the access to Duke Energy's interconnection facilities well graded, drained and properly maintained?

☐ Yes ☐ No

☐ Provide photos of the access road.

4. OVERHEAD LINE CONSTRUCTION AND EQUIPMENT INSTALLATION

4.1. Pole ID#1

☐ Provide one or two photos to establish the position of the pole relative to other adjacent poles.

☐ Provide two or three close-up photos of the pole.

4.1.1. Pole ID#1 - Immediate Safety Issues

Were there any Immediate Safety Issues? If yes, complete the information below for each issue.

☐ Yes ☐ No

Item #:

Location/Equipment:

Describe Problem:

Has the problem been corrected? ☐ Yes ☐ No If No, fill out the timetable for making the correction below

Correction Timetable:

Describe Correction:

☐ Provide photos of the problem

☐ Provide photos of the correction (if applicable)

4.1.2. Pole ID#1 - Potential Reliability or Power Quality Issues

Were there any Potential Reliability or Power Quality Issues? If yes, complete the information below for each issue.

☐ Yes ☐ No

Item #:

Location/Equipment:

Describe Problem:

Has the problem been corrected? ☐ Yes ☐ No If No, fill out the timetable for making the correction below

Correction Timetable:

Describe Correction:

☐ Provide photos of the problem

☐ Provide photos of the correction (if applicable)

4.2. Pole ID#2

☐ Provide one or two photos to establish the position of the pole relative to other adjacent poles.

☐ Provide two or three close-up photos of the pole.

4.2.1. Pole ID#2 - Immediate Safety Issues

Were there any Immediate Safety Issues? If yes, complete the information below for each issue.

☐ Yes ☐ No

Item #:	
Location/Equipment:	
Describe Problem:	
Has the problem been corrected?	☐ Yes ☐ No If No, fill out the timetable for making the correction below
	Correction Timetable:
Describe Correction:	

☐ Provide photos of the problem

☐ Provide photos of the correction (if applicable)

4.2.2. Pole ID#2 **- Potential Reliability or Power Quality Issues**

Were there any Potential Reliability or Power Quality Issues? If yes, complete the information below for each issue.

☐ Yes ☐ No

Item #:

Location/Equipment:

Describe Problem:

Has the problem been corrected? ☐ Yes ☐ No If No, fill out the timetable for making the correction below

Correction Timetable:

Describe Correction:

☐ Provide photos of the problem

☐ Provide photos of the correction (if applicable)

Copy the template from 4.1 and 4.2 and continue with section 4.3, 4.4, 4.5, etc. following the same requirements until all overhead work is covered.

5. PAD-MOUNTED EQUIPMENT INSTALLATION

5.1. PME ID#1

☐ Provide one or two photos to establish the position of the equipment relative to other adjacent equipment.

☐ Provide close-up photos of the equipment.

5.1.1. PME ID#1 **- Immediate Safety Issues**

Were there any Immediate Safety Issues? If yes, complete the information below for each issue.

☐ Yes ☐ No

Item #:

Location/Equipment:

Describe Problem:

Has the problem been corrected? ☐ Yes ☐ No If No, fill out the timetable for making the correction below

Correction Timetable:

Describe Correction:

☐ Provide photos of the problem

☐ Provide photos of the correction (if applicable)

5.1.2. PME ID#1 - Potential Reliability or Power Quality Issues

Were there any Potential Reliability or Power Quality Issues? If yes, complete the information below for each issue.

☐ Yes ☐ No

Item #:

Location/Equipment:

Describe Problem:

Has the problem been corrected? ☐ Yes ☐ No If No, fill out the timetable for making the correction below

Correction Timetable:

Describe Correction:

☐ Provide photos of the problem

☐ Provide photos of the correction (if applicable)

5.2. PME ID#2

☐ Provide one or two photos to establish the position of the equipment relative to other adjacent equipment.

☐ Provide close-up photos of the equipment.

5.2.1. PME ID#2 - Immediate Safety Issues

Were there any Immediate Safety Issues? If yes, complete the information below for each issue.

☐ Yes ☐ No

Item #:

Location/Equipment:

Describe Problem:

Has the problem been corrected? ☐ Yes ☐ No If No, fill out the timetable for making the correction below

Correction Timetable:

Describe Correction:

☐ Provide photos of the problem

☐ Provide photos of the correction (if applicable)

5.2.2. PME ID#2 - Potential Reliability or Power Quality Issues

Were there any Potential Reliability or Power Quality Issues? If yes, complete the information below for each issue.

☐ Yes ☐ No

Item #:

Location/Equipment:

Describe Problem:

Has the problem been corrected? ☐ Yes ☐ No If No, fill out the timetable for making the correction below

Correction Timetable:

Describe Correction:

☐ Provide photos of the problem

☐ Provide photos of the correction (if applicable)

Copy the template from 5.1 and 5.2 and continue with section 5.3, 5.4, 5.5, etc. following the same requirements until all pad-mounted work is covered.

6. APPENDIX A – COMPLETE INVERTER SETTINGS

Utility-scale PV Periodic Inspection Program
Self-inspection Plan

For Distribution Connected Utility-scale Solar Generating Facilities (>=1MW) in DEC and DEP

Summary

This document defines a self-inspection plan for all existing in-service utility-scale PV facilities in DEC and DEP, which can be economically implemented by the Interconnection Customers and can help Duke Energy (Duke) maintain a database of DER compliance to applicable standards and codes.

Background

Approximately 300 utility-scale solar generating facilities interconnected to Duke's distribution grid before the implementation of an interconnection commissioning process in mid-2016. Many of these facilities have never been inspected by Duke and could be a risk to the safety, reliability, and power quality of the distribution grid. To address these concerns, Duke is establishing a periodic inspection program to ensure the safety, reliability, and power quality of all utility-scale PV facilities. All existing in-service utility-scale PV facilities in DEC and DEP are required to perform self-inspection and demonstrate the generating facility's compliance with applicable standards and codes. This program includes the utility-scale PV facilities that were commissioned under Duke's interconnection commissioning process to ensure they are continuing to adhere to applicable standards, codes, and utility requirements.

Objectives

1. Continuously improve the safety, reliability, power quality, and contractual compliance of utility-scale PV facilities in North Carolina and South Carolina.
2. Continuously ensure the operational compliance of utility-scale PV facilities according to IEEE Std 1547.
3. Encourage Interconnection Customers to maintain and operate utility-scale PV facilities safely and reliably.
4. Maintain accurate DER facility data necessary for power system modeling, planning, and operations.
5. Provide Interconnection Customers with flexibility in choosing inspection service providers.
6. Manage a high volume of utility-scale PV facilities effectively and efficiently.

Self-inspection Plan Description

Definition

Self-inspection Instruction Manual – A comprehensive document to help the Interconnection Customers understand the requirements of self-inspection and inspection report. It includes a sample report and a report template.

Self-inspection Notification Package – The package includes: self-inspection process document, self-inspection instruction manual, Duke-approved SLD on file, tables of Duke approved equipment and expected inverter settings, etc.

Full-scale Audit Inspection – Duke may choose to inspect an interconnected Generating Facility. The scope of such inspection may include all the requirements of the self-inspection, plus the periodic commissioning test.

Immediate safety issues – These are the construction quality problems that violate industry codes and standards, and are imminently likely to endanger life or property or damage either the utility's system or customer's generating facilities.

Potential reliability or power quality issues – These are the construction quality problems that may develop over time into something with the potential to either cause disruption or deterioration of service to other customers.

Scope of Work

The self-inspection together with the inspection report shall cover the following subjects:

- DER as-built installation evaluation
- Interconnection equipment settings check
- Access to Duke interconnection facilities
- Overhead construction and equipment installation
- Pad-mounted construction and equipment installation

Self-inspection Process

1. Periodic inspection is required as continuous compliance needs to be verified. Different components in a Generating Facility may require different self-inspection cycles.
    a. The self-inspection and report on construction quality and site maintenance is required every 5 years for the Generating Facilities with all previously identified construction quality issues addressed and without new construction (5-year cycle).

b. The self-inspection and report on interconnection equipment settings is required annually (1-year cycle).

c. The proof of clear access to Duke Interconnection Facilities is required annually (1-year cycle).

2. Duke will maintain a database of compliance risk of all interconnected Generating Facilities under the scope of the periodic inspection program. The facilities with high risk score will be selected for self-inspection first. The following criteria will be applied to determine the compliance risk score of an interconnected Generating Facility:

    a. Major site reconstruction or inverter replacement due to Duke's system upgrade, or natural disasters (hurricane, earthquake, tornado, storm, etc.)

    b. Number of years in service since the last successful inspection and cease-to-energize test

    c. Results of last inspection or self-inspection

    d. Complaints received from other retail load customers

    e. Reported and investigated DER operational issue that is triggered by cause inside the Generating Facility

    f. Revenue meter data screening results

    g. Random selection

3. The Interconnection Customers will be notified by a Duke representative when their Generating Facilities are selected for self-inspection. Along with the notice, a self-inspection notification package shall be provided to each customer. Notices may be delivered to customers on a quarterly or semi-annual schedule to spread the report submissions throughout the year.

4. The self-inspection is at the Interconnection Customer's expense, and the customer can choose any qualified resource on the market to perform self-inspection following the Duke Energy *INSTRUCTION MANUAL for SELF-INSPECTION of DISTRIBUTION CONNECTED UTILITY-SCALE SOLAR*. The customer is required to submit the self-inspection report within 60 calendar days of the notice. Duke will send reminder to the Interconnection Customer 14 days before the self-inspection report due date.

5. Duke or a designated engineering services company acting in place of Duke will collect the self-inspection report and perform an engineering review.

Corrective Action Process

Interconnection Customers shall complete the self-inspection and submit the inspection report following the *INSTRUCTION MANUAL*. All identified deficiencies in the inspection report must be addressed in a timely manner at the Interconnection Customer's expense.

- **Immediate safety issues** shall be corrected immediately. The proof of correction must be provided in the self-inspection report.
- **Potential reliability or power quality issues** require engineering supervision and shall be corrected during operations and maintenance cycles. It is highly recommended to fix these issues and provide proof of correction when submitting in the self-inspection report. At a minimum, the action plan to correct these issues with a definite timeline is required in the self-inspection report. All corrections must be made no later than 6 months from the date of inspection report.

If any action from Duke is deemed necessary due to any issues not identified, or identified but not fully addressed in the self-inspection report, Duke will use the provisions in the section 6.5 of the 2019 NCIP Order to inspect the medium voltage AC side of operating Generating Facilities and invoice the applicable Interconnection Customer for the costs of the inspection. Specifically, the Full-scale Audit Inspection of the Generating Facility will be required at the Interconnection Customer's expense if any of the following conditions is met.

1. The Interconnection Customer failed to respond to the self-inspection notice after reminder.
2. The Interconnection Customer failed to sufficiently, adequeately, and independently execute the self-inspection on their own by following the *INSTRUCTION MANUAL*.
3. The Interconnection Customer cannot find other resources to perform the self-inspection and requests Duke to provide inspection of the Generating Facility.

Effective Date

- Q3, 2020 – Pilot the program with selected Uninspected Generating Facilities.
- Full deployment of self-inspection program is expected in 2021.

Version History

Revision 0 (4/15/2020)

- First issuance

INSTRUCTION MANUAL
for
SELF-INSPECTION
of
DISTRIBUTION CONNECTED UTILITY-SCALE SOLAR (>=1MW)

North Carolina
and
South Carolina

April 2020

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INTRODUCTION

Duke Energy is establishing a periodic inspection program to ensure the safety, reliability, and power quality of all utility-scale PV facilities. All existing in-service utility-scale PV facilities in DEC and DEP are required to perform self-inspection and demonstrate the generating facility's compliance with applicable standards and codes. This program includes the utility-scale PV facilities that were commissioned under Duke Energy's interconnection commissioning process, to ensure they are continuing to adhere to applicable standards, codes, and utility requirements.

This document is designed to help Interconnection Customers understand the requirements of the self-inspection, and to achieve the following objectives.

- Continuously improve the safety, reliability, power quality, and contractual compliance of utility-scale PV facilities in North Carolina and South Carolina.
- Continuously ensure the operational compliance of utility-scale PV facilities according to IEEE Std 1547.
- Encourage Interconnection Customers to maintain and operate utility-scale PV facilities safely and reliably.
- Maintain accurate DER facility data necessary for power sytem modeling, planning, and operations.
- Provide the Interconnection Customers with flexibility in choosing inspection service providers.
- Manage a high volume of utility-scale PV facilities effectively and efficiently.

The Interconnection Customer shall complete the self-inspection and submit the inspection report following these instructions. All identified deficiencies in the inspection report must be addressed in a timely manner at the Interconnection Customer's cost. If any action from Duke Energy is deemed necessary due to any issues not identified, or identified but not fully addressed in the self-inspection report, Duke Energy will use the provisions in the section 6.5 of the 2019 NCIP

Order to inspect the medium voltage AC side of operating Generating Facilities and invoice the applicable Interconnection Customer for the costs of the inspection.

The description of Periodic Inspection Program Self-inspection Plan and other relevant materials can be accessed at Duke Energy's website at (choose North Carolina or South Carolina):
https://www.duke-energy.com/business/products/renewables/generate-your-own/tsrg

This Self-inspection Instruction Manual is prepared and maintained by Duke Energy DER Technical Standards Group and Advanced Energy Solar Commissioning Team. Questions or comments can be sent to:

- DER - Technical Standards <DER-TechnicalStandards@duke-energy.com>
- AE Solar Commissioning <solarcommissioning@advancedenergy.org>

SCOPE OF SELF-INSPECTION

The primary purpose of the periodic interconnection inspection is to ensure the medium voltage (MV) construction and the approved interconnection equipment of the Interconnected Generating Facilities (electrical equipment from the AC side of the inverters to the point of interconnection) are installed and configured in accordance with applicable codes and standards.

The inspector shall reference the following list of codes, standards, agreements, and requirements in the self-inspection and report preparation:

- The approved single line diagram (SLD), Interconnection Request, Interconnection Agreement, and other Duke Energy requirements
- National Electrical Safety Code (NESC)
- National Electrical Code (NEC)
- IEEE Std 1547 and 1547.1
- Duke Energy distribution construction standards
- Duke Energy DER Construction Reference Guide
- Duke Energy's Service Requirements Manual (White Book)
- Inverter manufacturer installation requirements

The self-inspection scope includes the following aspects:

1. DER as-built installation evaluation
2. Interconnection equipment settings
3. Access to Duke Energy interconnection facilities
4. Overhead construction and equipment installation
5. Pad-mounted construction and equipment installation

The details of these requirements are further explained in the following sections.

1. DER AS-BUILT INSTALLATION EVALUATION

The DER as-built installation evaluation is to verify that the installed Interconnection Customer's Interconnection Facility matches the approved documents on file with Duke Energy.

A summary of key site information from the documentation on file with Duke Energy will be provided to the Interconnection Customer in the Self-inspection Notification Package.

Site Name	
Site Address	
IPP Number (when applicable)	
Maximum Physical Export Capability	
Interconnection Voltage	
Commenced Operation Date	
MV Transformers (Quantity, Size, Grounding)	
Inverters (Quantity, Manufacturer, Model)	
Last Commissioning Test Date	

Self-inspection Requirements:

1. Review the site information provided by Duke Energy and provide the necessary updates.
2. Evaluate and confirm the system installation is in accordance with the electrical design as submitted with the application for interconnection.
    a. Record the NRTL Label, file number, and listed intended use of each component, subsystem, and/or system in the interconnection system.
    b. Collect the inverter data: nameplate photo, quantity, manufacturer, model, kVA rating, serial number, manufacture date.
    c. Collect the medium voltage transformer nameplate data: nameplate photo, quantity, kVA rating, winding type and grounding configuration.
    d. Save the collected data in electronic format using the provided report template.

2. INTERCONNECTION EQUIPMENT SETTINGS

This step is to verify the interconnection equipment settings match the required settings in the Interconnect Agreement and are in compliance with IEEE Std 1547.

A summary of the expected inverter settings will be provided to Interconnection Customer in the Self-inspection Notification Package. Typical settings for Duke Energy Carolinas (DEC) and Duke Energy Progress (DEP) are provided in the tables below. All advanced grid functions must be disabled (e.g. LVRT, HVRT, volt-var).

DEC Interconnection Agreement Default Settings		
Parameter	**Value**	**Time (sec)**
Under Voltage 1	0.88 per unit	2
Under Voltage 2	0.50 per unit	0.16
Over Voltage 1	1.10 per unit	1
Over Voltage 2	1.20 per unit	0.16
Under Frequency 1	59.3 Hz	0.16
Over Frequency 1	60.5 Hz	0.16
Power Factor	1*	--
Grid Reconnect Timer	--	300
Advanced Grid Functions (e.g. LVRT, HVRT, volt-var)	Disabled	--

* Unless otherwise noted in IA

DEP Interconnection Agreement Default Settings		
Parameter	**Value**	**Time (sec)**
Under Voltage 1	0.90 per unit	0.167
Under Voltage 2	0.90 per unit	0.167
Over Voltage 1	1.10 per unit	0.167
Over Voltage 2	1.10 per unit	0.167
Under Frequency 1	59.3 Hz	0.167
Over Frequency 1	60.5 Hz	0.16
Power Factor	1*	--
Grid Reconnect Timer	--	300
Advanced Grid Functions (e.g. LVRT, HVRT, volt-var)	Disabled	--

* Unless otherwise noted in IA

Self-inspection Requirements:

1. Verify and record the settings at each inverter.

    a. The settings may be verified at a central control interface if the DER system consists of a large number of inverters (>10). In such case, samples of inverters (at least 3) at each transformer should be randomly selected to verify the settings at the inverters. During the next inspection cycle, include inverters that were not verified previously.

    b. In the case the DER system is designed to use a customer-owned recloser, plant controller, or other devices to provide protective function instead of inverters, or in conjunction with inverters, verify the protective function settings in the control of the corresponding device.

2. Verify the active power output limit of the Generating Facility does not exceed the Maximum Physical Export Capability in the Interconnection Agreement.

3. ACCESS TO DUKE ENERGY INTERCONNECTION FACILITIES

The Interconnection Customer must provide a well-drained access road, preferably with a gravel bed, to the Duke Energy meter and recloser poles. The requirements are listed in the Duke Energy Service Requirements Manual (White Book) Figure 71A and 71B.

COMPANY PROVIDES ALL FACILITIES TO P.O.D. CUSTOMER TO PROVIDE A LOCATION FOR COMPANY FACILITIES THAT MUST:

- *BE LOCATED OUT OF WETLANDS AND OTHER AREAS SUBJECT TO FLOODING.*
- *HAVE MAINTAINED ACCESS ROADS, PREFERABLY WITH GRAVEL BED AND ADEQUATE DRAINAGE FOR ACCESS BY STANDARD COMPANY EQUIPMENT DURING ALL ADVERSE WEATHER CONDITIONS.*
- *BE FREE OF VEGETATION FOR BUCKET TRUCK ACCESS (15 FOOT CLEARANCE, 360 DEGREE RADIUS).*
- *BE LOCATED OUTSIDE A LOCKED GATE OR FACILITY FENCE. IF THIS CANNOT BE ACCOMPLISHED, ANY GATES OR ACCESS POINTS MUST ACCOMMODATE A COMPANY LOCK AND BE ACCESSIBLE AT ANY AND ALL TIMES.*

NOTE: Where Duke Energy Facilities cannot be located outside a locked gate, the Duke Energy Account Manager can obtain a Duke Energy lock from the local Company Operations Center. The Company lock can be interlocked with the site owner lock.

<u>Self-inspection Requirements:</u>

1. Inspect the access to Duke's Interconnection Facilities at least once a year.
2. Make sure proper maintenance and necessary corrections are applied to meet the requirements.

4. OVERHEAD LINE CONSTRUCTION AND EQUIPMENT INSTALLATION

The requirements in this section shall be applied to all customer overhead facilities beyond Duke Energy's last pole (transition pole, meter pole or recloser pole), which may include but is not limited to the following:

- Riser pole
- Meter pole
- Recloser pole
- Gang Operated Load Break Switch (GOAB Switch)
- Overhead Transformer pole
- Angle pole
- Tangent pole

Self-inspection Requirements:

The inspector shall inspect the Interconnection Customer's overhead facility and identify construction quality issues in the following two categories.

- **Immediate safety issues** - these are the construction quality problems that violate industry codes and standards, and are imminently likely to endanger life or property or damage either the utility's system or customer's generating facilities. These problems shall be corrected immediately. The proof of correction must be provided in the self-inspection report.
- **Potential reliability or power quality issues** - these are the construction quality problems that may develop over time into something with the potential to either cause disruption or deterioration of service to other customers. These problems require engineering supervision and shall be corrected during operations and maintenance cycles. It is highly recommended to fix these issues and provide proof of correction when submitting the self-inspection report. At a minimum, the action plan to correct these issues with a definite timeline is required in the self-inspection report.

At each overhead structure, the inspector may use the following list of questions during the inspection to help identify potential issues.

1. Is there overgrown vegetation around the pole or are tree limbs within 8 feet of the closest primary conductor?

2. Does the MV cable, conductor or jumper have proper insulation and ampacity ratings? Riser cables have a lower summer ampacity than underground cables.

3. Is there any insufficient Phase-to-Phase and Phase-to-Ground Clearance issue? Duke Energy requires a minimum phase-to-phase and phase-to-ground clearance of 18 inches for covered jumpers and 24 inches for bare jumpers.

4. Is there any grounding issue, including but not limited to: component is not grounded, missing ground connections, undersized grounding conductor, grounding conductor not securely stapled, etc.?

5. Is the lightning arrester the correct voltage rating and appropriately installed? 23 kV interconnections require 18 kV arresters and 12 kV interconnections require 10 kV arresters.

6. Is there wildlife protection? This includes minimum 600 volt insulated covered jumpers and wildlife guards on arresters, transformer bushings, PTs and recloser bushings.

7. Is there a proper pole identification label and fuse size and type label.?

8. At the riser pole, is the riser conduit installed properly? Is the cable terminated properly (orientation)?

9. At the GOAB pole, is the control rod Insulator properly installed? Is the operating handle and control rod securely mounted (check for loose connection)?

10. At the meter pole, is the meter enclosure properly grounded? Is the wire connection inside the meter enclosure secure?

11. At each guyed pole, are the guy wires properly bounded to the system neutral and grounded? Is the guy insulator installed properly?

5. PAD-MOUNTED EQUIPMENT INSTALLATION

The requirements in this section shall be applied to any customer pad-mounted facilities beyond Duke Energy's last pole (transition pole, meter pole or recloser pole), which may include but not limited to the following:

- Switchgear
- Meter
- Step-up transformer
- Auxiliary transformer
- Junction enclosure
- Inverter
- Recloser

Self-inspection Requirements:

The inspector shall inspect the pad-mounted facilities and identify construction quality issues in the following two categories.

- **Immediate safety issues** - these are the construction quality problems that violate industry codes and standards, and are imminently likely to endanger life or property or damage either the utility's system or customer's generating facilities. These problems shall be corrected immediately. The proof of correction must be provided in the self-inspection report.
- **Potential reliability or power quality issues** - these are the construction quality problems that may develop over time into something with the potential to either cause disruption or deterioration of service to other customers. These problems require engineering supervision and shall be corrected during operations and maintenance cycles. It is highly recommended to fix these issues and provide proof of correction when submitting in the self-inspection report. At a minimum, the action plan to correct these issues with a definite timeline is required in the self-inspection report.

At each pad-mounted equipment, the inspector may use the following list of questions during the inspection to help identify potential issues.

1. Is the enclosure secured to the concrete pad?

2. Are all MV cable elbows fully seated so that no colored or serated latch indicator ring is visible on the bushing?

3. Is there oil leakage inside the compartments of the transformer?

4. Does the cable have a proper rating to carry the maximum current?

5. Is the H0 neutral bushing in the MV transformers properly connected to the internal transformer ground loop?

6. Is there any cable routing issue that may violate the 12X bending radius limit, or may cause insufficient clearance?

7. Does it have sufficient grounding? Is there any missing or disconnected ground cable? Is there any ungrounded component? Does it have a continuous ground loop between the ground pads in the primary and secondary compartments?

8. Are the lighting arresters installed properly? Look for any missing arresters, blown arresters, loose elbow connections, missing or incorrectly connected electrostatic drain wires, unterminated concentric neutral conductor, etc.

9. Is the correct tap changer setting of transformers selected to ensure nominal voltage on both MV and LV sides?

REPORTING REQUIREMENT

A standardized report outline is defined in this section to help the interconnection customers prepare the self-inspection report. Further information can be found in the sample report (Appendix I) and the report template (Appendix II).

The inspection report must be prepared under the responsible charge of a professional engineer (PE) and must be sealed by the PE. The Interconnection Customer and the inspector may choose any format for the cover page, summary section, and table of content. The main body of the inspection report should be prepared using the outline as follows.

1. DER AS-BUILT INSTALLATION EVALUATION

1.1 Agreement with Utility Documentation

Provide the as-built site information. If any discrepancy is found between the Duke provided site information and the as-built site information, highlight the difference and submit corresponding documentation to Duke Energy.

1.2 Inverter Information

- Confirm all inverters are UL 1741 listed.
- Provide one photo of the nameplate for each model inverter. Only one photo is required if the site consists of multiple units of the same brand and model.
- Provide photo proof of UL 1741 listing if the listing stamp is not on the nameplate. Only one photo is required if the site consists of multiple units of the same brand and model.
- Provide inverter data in electronic format using the Excel report template.

1.3 Transformer Information

- Confirm the transformer winding configuration.
- Provide a photo of the nameplate for each model transformer. Only one photo is required if the site consists of multiple units of the same brand and model.
- Provide transformer data in electronic format using the Execl report template.

2. INTERCONNECTION EQUIPMENT SETTINGS

- Provide tabulated results of a list of the as-found settings and as-left settings of the inverters.
- Provide proof of inverter settings, which could consist of setting files, screenshots, photos of inverter HMI, etc.

3. Access to Duke Energy Interconnection Facilities

- Provide a photo of the Duke Energy Interconnection Facilities at the POI as proof of meeting all requirements.

4. Overhead Line Construction and Equipment Installation

4.1 Pole #1

- Each pole shall be identified with an ID matching the SLD or use self-explained text such as “riser pole” or “meter pole.”
- Provide at least one photo showing an overview of the structure and telling its relative location to the rest of the facility.
- Provide at least two close up photos of the top of the pole from different angles to show details.

4.1.1 Pole #1 – Immediate Safety Issues

- Describe each immediate safety issue identified at pole #1.
- Provide photos taken at the inspection to illustrate the issue.
- Provide photos taken after correction is applied to prove the issue has been resolved.

4.1.2 Pole #1 – Potential Reliability or Power Quality Issues

- Describe each potential reliability or power quality issue identified at pole #1.
- Provide photos taken at the inspection to illustrate the issue.
- Provide photos of the correction if already completed.
- If the issue has not been corrected, explain the action plan to correct the issue with a definite timeline.

4.2 Pole #2

4.2.1 Pole #2 – Immediate Safety Issues

4.2.2 Pole #2 – Potential Reliability or Power Quality Issues

(Continue with section 4.3, 4.4, 4.5, etc. following the same requirements until all overhead work is covered.)

5. Pad-mounted Equipment Installation

5.1 Pad-mounted equipment #1

- Each pad-mounted equipment shall be identified with ID matching the SLD or use self-explained text such as “step-up transformer #1” or “auxiliary transformer.”
- Provide at least one photo showing an overview of the structure and telling its relative location to the rest of the facility.
- Provide outside photos of the pad-mounted equipment
- Provide photos of the inside of the pad-mounted equipment showing
  - The medium voltage elbows and the ground grid
  - The primary side and the secondary side
  - The ground grid
  - The connection to the H0 grounding bushing
  - The connection to the X0 grounding bushing
  - The connections to the secondary bushings

5.1.1 Pad-mounted equipment #1 – Immediate Safety Issues

- Describe each immediate safety issue identified at pad-mounted equipment #1.
- Provide photos taken at the inspection to illustrate the issue.
- Provide photos taken after correction is applied to prove the issue has been resolved.

5.1.2 Pad-mounted equipment #1 – Potential Reliability or Power Quality Issues

- Describe each potential reliability or power quality issue identified at pad-mounted equipment #1.
- Provide photos taken at the inspection to illustrate the issue.
- Provide photos of the correction if already completed.
- If the issue has not been corrected, explain the action plan to correct the issue with a definite timeline.

5.2 Pad-mounted equipment #2

5.2.1 Pad-mounted equipment #2 – Immediate Safety Issues

5.2.2 Pad-mounted equipment #2 – Potential Reliability or Power Quality Issues

(Continue with section 5.3, 5.4, 5.5, etc. following the same requirements until all pad-mounted work is covered.)

APPENDIX I . SAMPLE REPORT

APPENDIX II . REPORT TEMPLATE

VERSION HISTORY

Draft 1 (4/15/2020)

- Initial draft shared through TSRG

Attachment H

Periodic Inspection Program
Self-inspection Plan – Update

Kevin Chen 4/28/2020

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- Self-inspection Process Update
- Timeline Moving Forward
- Q&A, open discussion

Recently shared documents:

- Self-inspection Process (draft)
- Self-inspection Instruction Manual (draft)
  - Self-Inspection Sample Report (sample)
  - Report Template in WORD format (draft)
  - Report Table Template in Excel format (draft)

Everything from existing commissioning process:

- DER Construction Reference Guide (Feb 2020)
- Duke Energy Distribution Construction Standards (through contractor portal upon request)
- Previous MV inspection training materials (presentations and video)

Additional material under development:

- Full list of issues from pilot periodic inspection in 2018 and 2019

Overview

- There are approximately 300 Generating Facilities that were interconnected to Duke systems prior to the point in time at which Duke implemented an inspection program ("Uninspected Facilities").
- The 2019 NCIP Order approved the addition of Sections 6.5.2, 6.5.3 and 6.5.4 to the NCIP. Such sections authorize Duke to inspect the medium voltage AC side of operating Generating Facilities and invoice the applicable Interconnection Customer for the costs of the inspection.
- Duke is pursuing a collaborative effort through the TSRG to develop a more flexible, efficient, and possibly less-expense approach to inspect the remaining Uninspected Facilities ("Self-inspection" process).
- While the Uninspected Facilities are going to be self-inspected first, the process is designed to cover all Existing Distribution Connected Utility-scale Solar in DEC and DEP (>=1MW).

- **Immediate safety issues** – These are the construction quality problems that violate industry codes and standards, and are imminently likely to endanger life or property or damage either the utility's system or customer's generating facilities.
- **Potential reliability or power quality issues** – These are the construction quality problems that may develop over time into something with the potential to either cause disruption or deterioration of service to other customers.
- **Full-scale Audit Inspection** – Duke may choose to inspect an interconnected Generating Facility. The scope of such inspection may include all the requirements of the self-inspection, plus the periodic commissioning test.

6.5.4 The Utility shall also be entitled to inspect the medium voltage AC side of an Interconnected Generating Facility in the event that the Utility identifies or becomes aware of any condition that (1) has the potential to either cause disruption or deterioration of service to other customers served from the same electric system or cause damage to the Utility's System or Affected Systems, or (2) is imminently likely to endanger life or property or cause a material adverse effect on the security of, or damage to the Utility's System, the Utility's Interconnection Facilities or the systems of others to which the Utility's System is directly connected. The Interconnection Customer shall pay the actual cost of such inspection within 30 Business Days after the Utility provides a written invoice for such costs.

NCIP Section 6.5.4, Effective June 14, 2019, Docket No. E-100, Sub 101

Scope of Self-inspection

- The self-inspection together with the inspection report shall cover the following:
  1. DER as-built installation evaluation
  2. Interconnection equipment settings check
  3. Access to Duke interconnection facilities
  4. Overhead construction and equipment installation
  5. Pad-mounted construction and equipment installation

- Different components in a Generating Facility may require different self-inspection cycles.
  1. MV facility construction quality and site maintenance – every 5 years (**5-year cycle**).
  2. Interconnection equipment settings – annually (**1-year cycle**).
  3. Access road to Duke Interconnection Facilities – annually (**1-year cycle**).

Process Description

Project Selection

- Facilities with higher risk score are selected first.
- Duke to notify the customer
- Duke to remind the customer 14 days before the report due date

Self-inspection

- Customer to choose any qualified resource to perform self-inspection following the *INSTRUCTION MANUAL*
- Customer to submit the self-inspection report within 60 calendar days of the notice

Corrective Action

- Immediate safety issues – proof of correction must be included in the report
- Potential reliability or power quality issues – correction plan must be provided in the report, all corrections must complete in 6 month from the report.

Review and Update

- Duke will collect the self-inspection report and perform an engineering review.
- Duke will maintain a database of compliance

- The Full-scale Audit Inspection of the Generating Facility will be required at the expense of the Interconnection Customer if any of the following conditions is met.

1. The Interconnection Customer failed to respond to the self-inspection notice after the reminder.

2. The Interconnection Customer failed to sufficiently, adequately, and independently execute the self-inspection on their own by following the *INSTRUCTION MANUAL*.

3. The Interconnection Customer cannot find other resources to perform the self-inspection and requests Duke to provide inspection of the Generating Facility.

Agenda

- Self-inspection Process Update
- Timeline Moving Forward
- Q&A, open discussion

Expected Timeline

- 1/21/2020 – Presented the initial version of self-inspection plan at TSRG meeting
- 4/28/2020 – Present the self-inspection process update at TSRG meeting
- Q2, 2020 – Collect feedback and refine the self-inspection process

Please provide feedback or suggestion to me. (kevin.chen@duke-energy.com)

- Q2, 2020 – Prepare for training materials on the topic of self-inspection
- Q3, 2020 – Pilot the program with volunteer customers
  - Practice the self-inspection following the *INSTRUCTION MANUAL*
  - Evaluate the range of cost of running the program
  - Further refine the self-inspection process with lessons learned from the pilot
- Full deployment of self-inspection program may be in 2021

- Self-inspection Process Update
- Timeline Moving Forward
- Q&A, open discussion

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Optional Slides

Risk Score and Project Selection

- Duke will maintain a database of compliance risk of all interconnected Generating Facilities under the scope of the periodic inspection program.
- The facilities with high risk score will be selected for self-inspection first.
- The following criteria will be applied to determine the compliance risk score:
  1. Major site reconstruction or inverter replacement
  2. Number of years in service since the last successful inspection and cease-to-energize test
  3. Results of last inspection or self-inspection
  4. Complaints received from other retail load customers
  5. Reported and investigated DER operational issue that is triggered by cause inside the Generating Facility
  6. Revenue meter data screening results
  7. Random selection

- Duke will notify the Interconnection Customers when their Generating Facilities are selected for self-inspection.
- The customer is required to perform self-inspection following the *INSTRUCTION MANUAL* and submit the self-inspection report within 60 calendar days of the notice.
- Duke will send reminder to the Interconnection Customer 14 days before the self-inspection report due date.
- Duke or a designated engineering services company acting in place of Duke will collect the self-inspection report and perform an engineering review.

Corrective Action

- All identified deficiencies in the inspection report must be addressed in a timely manner at the Interconnection Customer's expense.
  - Immediate safety issues shall be corrected immediately. The proof of correction must be provided in the self-inspection report.
  - Potential reliability or power quality issues require engineering supervision and shall be corrected during operations and maintenance cycles. <u>All corrections must be made no later than 6 months from the date of inspection report</u>.
- The Full-scale Audit Inspection of the Generating Facility will be required at the Interconnection Customer's expense if any of the following conditions is met.
  1. The Interconnection Customer failed to respond to the self-inspection notice after the reminder.
  2. The Interconnection Customer failed to sufficiently, adequately, and independently execute the self-inspection on their own by following the *INSTRUCTION MANUAL*.
  3. The Interconnection Customer cannot find other resources to perform the self-inspection and requests Duke to provide inspection of the Generating Facility.

Note: The T-D Interface Agreement - DER project was delayed due to a reorganization; however significant work has taken place.

Items where significant work has taken place since the January 2020 update:

Standard POI Recloser Settings: (Interface recloser, utility side of PCC)

Task: Determine standard passive settings and logic to optimize Ride-Through and System Protection.

Applies to: New sites addressed by enterprise standards project Change Management Plan. In-Service sites addressed with project described below.

Description or work: MATLAB and RTDS Modeling. This has been a tremendous level of work, consisting of months of time and thousands of system models. This represents tens of thousands of events modeled and aggregating the results

Goal: Optimize selectivity and performance for Ride-Through of transmission disturbances, Trip for faults when necessary, Trip for unintentional islands.

Current work: Meetings with Transmission System Planning, reviewing performance.

Next Steps:

- Worst Case: Additional modeling required.
- Best Case: Begin Pre-Deployment trial at some in-service sites.
- Seeing encouraging results.

Apply Standard POI Recloser Settings (in-service sites).

Task: Project to apply Standard POI Recloser Settings at in-service sites. (See item above for Standard POI Recloser Settings)

Applies to: In-service sites.

Description or work: Load new firmware, load new logic and settings, some sites will require a control replacement. Site will be off-line for several hours during replacement and checkout.

Goal: Implement protection performance improvements while minimizing the chance for Tripping due to a BES disturbance.

Schedule: Currently – scoping, project charter and budgeting. Field implementation planned for 2021 and 2022.

Determine capabilities, change settings on DER side of PCC (in-service sites):

Although outside the scope of the enterprise standards project for System Protection, it is recognized that changes are required on the DER side of the

PCC to address Ride-Through performance, depending on the capability, at in-service sites. This will require cooperation with DER owners to determine the capabilities of in-service sites and to coordinate and document setting changes. This related project has not been started. This is just a communication to recognize this work must take place.

Risk of Islanding (ROI) Studies with internal resources:

Task: Develop a quantifiable risk metric and a related threshold. Develop tools to study projects.

Applies to: This will be part of Change Management Plan for the enterprise standards project so it will, at a minimum, include future sites.

Description or work: Dynamic system modeling and studies for a statistically significant number of circuits with DER and related calculations to determine a quantifiable risk metric based on experiential data through the end of 2019.

Goal: Determine a risk-based metric that can be applied after evaluating a site with new standard POI Recloser settings. Passing or failing this review will impact decisions to install more protection. The proposed metric is Non-Detection-Zone Hours / Year / MW of installed DER.

Status: A strategy for performing the dynamic system models has been developed. This requires several months of modeling on a significant quantity of existing circuits with DER to determine a quantifiable risk metric. Modeling is planned to begin after the Standard POI Recloser settings are mature. Obtaining enterprise consensus on this idea depends on the results of the data generated by system models. The outcome is still unknown but looks promising.

Note: The above is an update to a bullet on slide 16 of the January update.

From the January presentation slide 6…
"After all preferable options are exhausted, Direct Transfer Trip (DTT) will be required."
This has not changed so there is no DTT update.

The future procedure may look like, apply initial "basic" screens, then apply advanced requirements and advanced study. Advanced study may include a study to determine the risk level for a site and compare against a quantifiable risk metric. After all tools are applied and failed, then DTT may be required.

Transmission Single Line-Ground Fault Scheme setting guidance:

Task: Determine standard settings for system protection performance.

Applies to: The transmission side of a T-D station due to high penetration of DER. This scheme addresses DER as a source to the transmission protection zone with L-G faults on the transmission system. This scheme is applied on the transmission system side of a T-D Station. Local settings at a DER are largely blind to L-G faults on the transmission system. This will be part of Change Management Plan for the enterprise standards project so it will, at a minimum, include future sites.

Description or work: Calculations to determine setting guidance.

Goal: Internal document for setting guidance for region P&C groups.

Schedule: Draft Written and is being reviewed by project team.

Standards Documentation: (Enterprise Standards Project)

Significant work has taken place. Integrated feedback from extended project team members on a draft document. This represents resolving hundreds of comments from dozens of extended team members. A new draft is being prepared.

Attachment J

Update and Discussion: Inverter Volt-Var Impact Study TSRG Meeting

Anthony C Williams, P.E.
Principal Engineer

DER Technical Standards
April 28, 2020

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Agenda

- Review the study
- Review the results
- Review the recommendations
- Next Steps and stakeholder discussion

Ground Rules

- All Stakeholder Group meetings, webinars and information exchange are designed solely to provide an open forum or means for the expression of various points of view in compliance with **antitrust laws**.
- Under no circumstances shall Stakeholder Group activities be used as a means for competing companies to reach any understanding, expressed or implied, which tends to **restrict competition**, or in any way, to impair the ability of participating members to exercise independent business judgment regarding matters affecting competition or regulatory positions.
- Proprietary information shall not be disclosed by any participant during any group meetings. In addition, no information of a secret or **proprietary** nature shall be made available to Stakeholder Group members.
- All proprietary information which may nonetheless be publicly disclosed by any participant during any group meeting shall be deemed to have been disclosed on a **non-confidential** basis, without any restrictions on use by anyone, except that no valid copyright or patent right shall be deemed to have been waived by such disclosure.

Logistics

- Clarifying questions will be answered during the presentation and stakeholder discussions at the end of the presentation
- Written feedback and comments will be solicited using comment form
  - Note questions then lets discuss – don't really want all the questions sent in that are mainly just for clarification – this takes a lot of time to address that could be spent on the comments and recommendations
  - It would be helpful to provide more Comment and Proposed Change details :

Stakeholder Name	Page Number	Paragraph Number	Comment	Proposed Change
example Question format	3	2	Why is winter data excluded?	None
example Comment format	7	4	Agree with the hours of study.	None
example Comment format	7	4	'the largest' is not clear	Replace 'the largest' with 'the maximum of the three phase currents"
example Recommendation format	10	3	The types of faults is too limited. Include single line to ground faults.	Include SLG faults

  - Being more specific makes the point, or main concerns, of the comment more apparent and allows a more direct response.
- Comments will be taken during the discussion and the form will be distributed after the meeting
- Share the feedback form using email: Duke-IEEE1547@duke-energy.com for stakeholders to provide their written feedback

Study Overview

- North Carolina Commission had tasked Duke to evaluate software-based controls of advanced inverters according to IEEE 1547-2018 standard.
- Evaluate the use of autonomous voltage-reactive power control functions at multiple inverter based distributed energy resources connected to the same feeder. Understand whether and how these controls cooperate with existing integrated voltage and VAR control systems.
- Evaluate the benefit of distributed voltage-reactive power controls at the distribution feeder level.
- Evaluate mitigation options required at the distribution feeder level to enable inverter reactive power based voltage control
- Conduct stakeholder process for inverter Volt-Var control functionalities consistent with IEEE 1547-2018 and the NC commission order.
- Comments remain open on the April report until June 1, 2020

Study Conclusions

- Several forms of control, setpoints, and combinations were considered
  - Under the study conditions a Volt-Var controller with 2% voltage slope between 1.04-1.06 pu, in combination with a Volt-Watt controller with 3% voltage slope between 1.06-1.09 pu will appears capable of reducing overvoltage conditions.
- Category B provides the most flexibility and margin for system changes over time
- DER near the station reduces the voltage concerns, reduces the reactive power flow, reduces the effectiveness of the inverter control, and reduces reactive capability requirements
- Once the voltage increases from DER interconnection, it generally remains elevated instead of returning to a lower level as load increases

Study Recommended Next Steps

- Conduct time series power flow studies to look at system response over many hours
- Voltage controller concerns
  - With the IVVC commitments, how will those controls manage DER reactive power if something other than a fixed pf is used
  - Consider how to control the feeder head compensation capacitor with autonomous controls
  - Impact on feeders with regulators that use resistive drop compensation; could require significant feeder changes if the drop compensation is removed to accommodate DER reactive power control
  - Use the time series to investigate how well the existing voltage control device controllers manage the DER reactive power
- Consider controls that get more var absorption to hold voltage under 1.05
- Review the impact of higher var absorption on the feeders (closer examination of reactive power flow on the feeder)
- Consider pf based controls for voltage independence and voltage reference to absorb less reactive power at steady state
- Identify potential pilot sites; following further clarification from the additional steps above

Stakeholder Feedback Form

Stakeholder Name	Page Number	Paragraph Number	Comment	Proposed Change

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- Variety of the voltage regulation on the 6 feeders

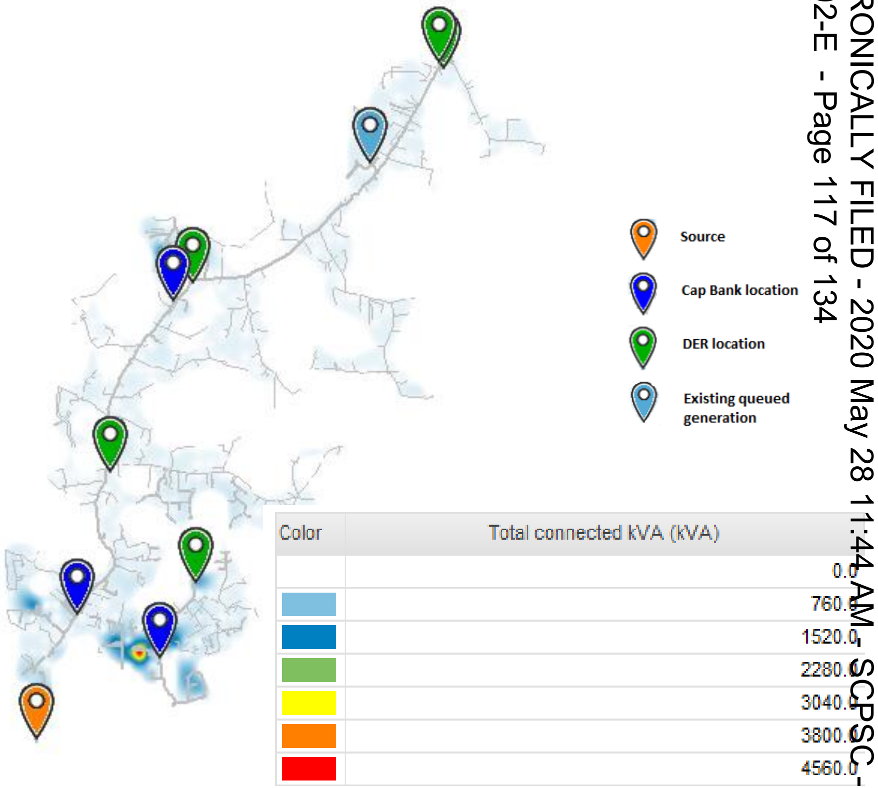
DEC	DEC	DEP	DEC	DEP	DEP	
Feeder B	Feeder C	Feeder D	Feeder A	Feeder F	Feeder E	
		X				Line Reg
			X			Feeder Reg
	X			X*		Feeder & Line Regs
					X*	LTC/Bus Reg
X						LTC/Bus Reg

Inverter Volt-Var Functionality - Study (DEC System)

- Feeder description – Feeder A off-peak

Feeder load characteristics	Value
Total load KW	1606.9
Total load Kvar	425.6
load PF	96.7%
Total load KVA	1662.3
Total KVA (peak load)	13735.6
Total load as a % of peak load	12.1%

Generation*	Value
Existing queued generation (end of feeder)	336 KW
Generation with smart inverter capability modeled at the head section	4 MW
Generation with smart inverter capability modeled at the middle section	2 MW
Generation with smart inverter capability modeled at the end section	4 MW



*Each 2 MW DER has a +/- 0.9 PF capability. The DER is connected to the feeder via a 0.48/23.9kV, %Z=5.75 and X/R ratio of 8.24 step up transformer.

DER Ability to Control Voltage

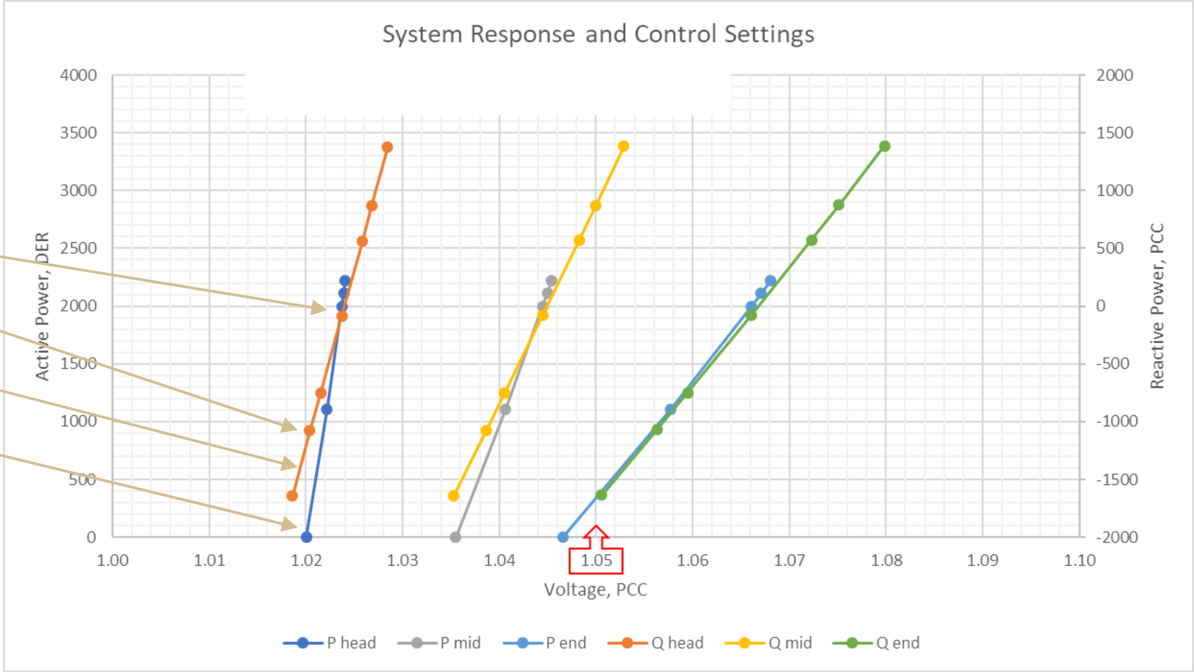
- Displays impact of injecting active and reactive power: dV/dP, dV/dQ
- Indicates there is limited ability to impact voltage and the ability changes based on location
- Worst case: vertical line
- Best case: horizontal line

Center at 2000 kW, 0 kVAR

0.9 pf point

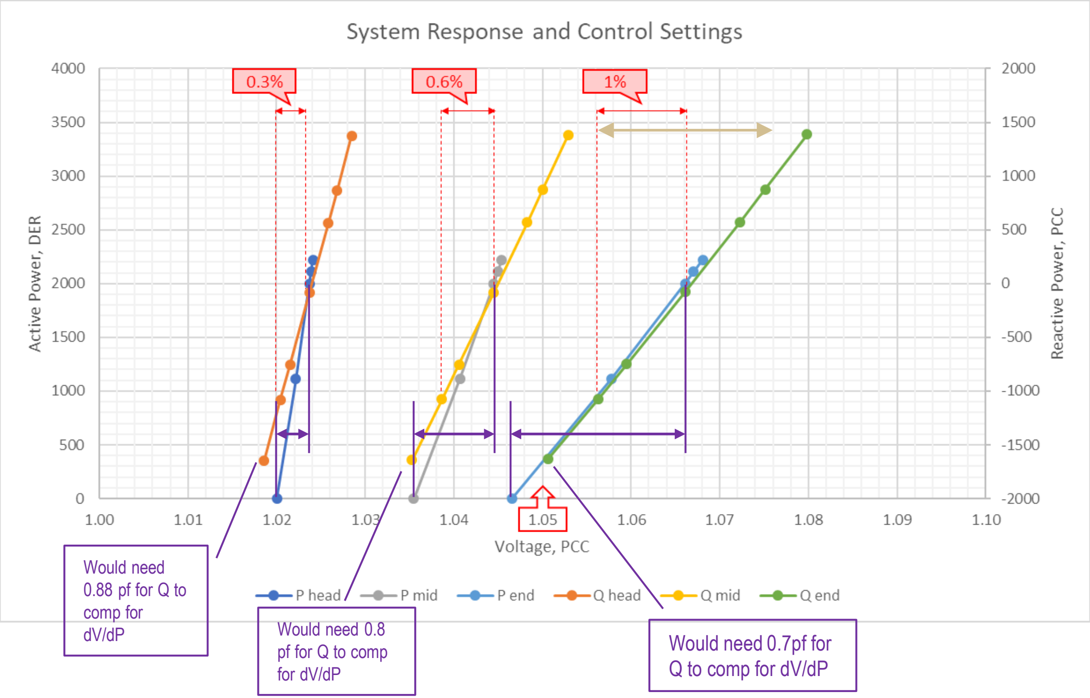
dQ line

dP line



Initial Conclusions from Charts

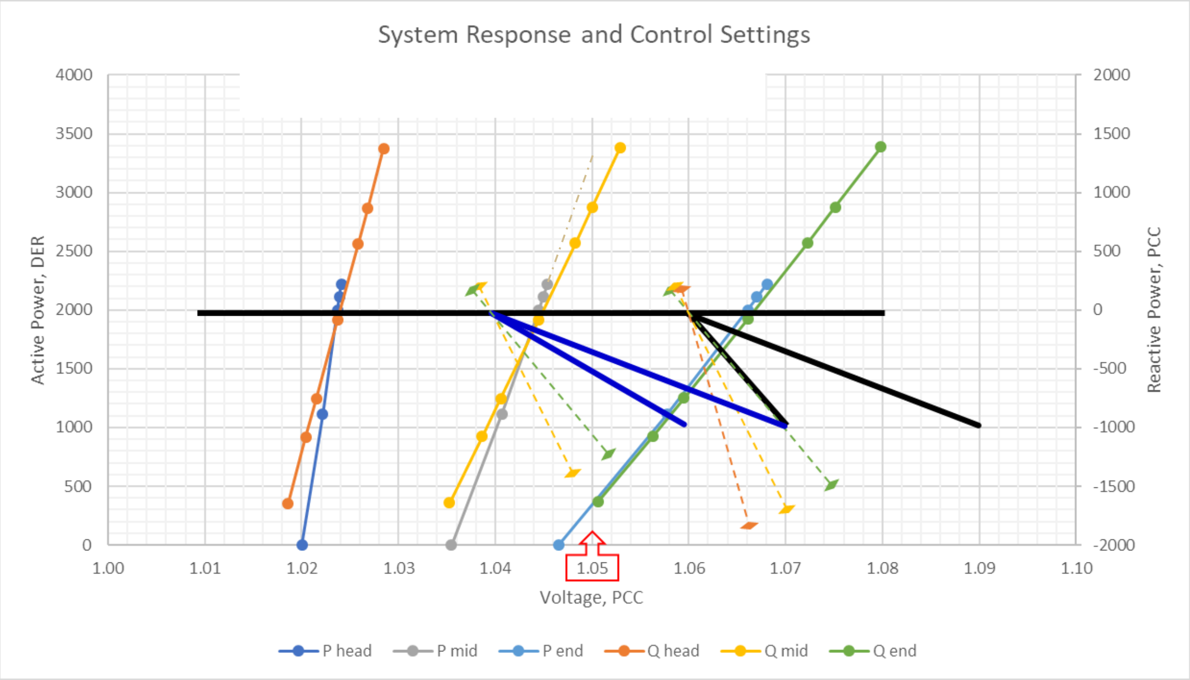
- Reactive power voltage control is limited to 0.3 - 1.0 %; even at 0.9 pf operation
- Only one location exceeds 1.05 V pu at unity
  - So, at that location, volt-var has impact
  - At the other locations, watt-var more likely to work or even a non-unity pf
  - And volt-watt at end would be an option
- The system response varies between 0.3 – 1.0 % dV pu/dQmax
  - Not a large control range or impact
  - Input to consider for controller slope limit



For Discussion Purposes Only

Application to Settings

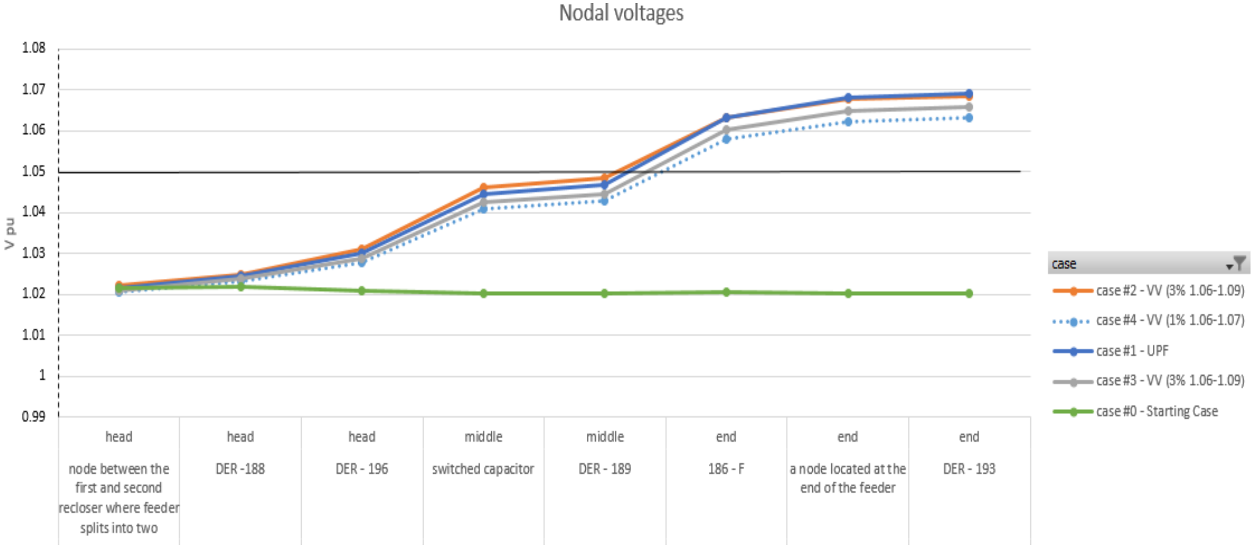
- Can add the controller lines directly on the chart
  - Deadband in the center, blue lines for 1.04 initiation, black lines for 1.06 initiation
- Controller slope options considered are shown
- Dashed lines represent the system response slopes; by color
- The goal is to keep the controller slope to the right of the system response



For Discussion Purposes Only

Inverter Volt-Var functionality – Study (DEC System Off Peak)

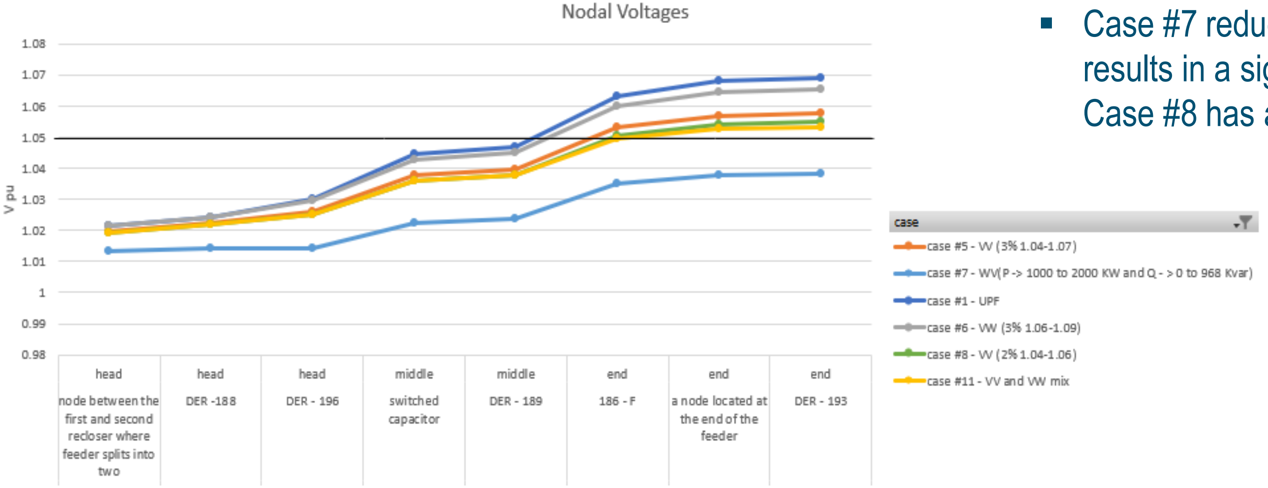
Cases	Caps	Number of DER units	Location	Control type	Control description	Gen outside 0.95 pf limit	Inverter KW	Kvar absorption at the PCC	Total_Kvar absorption at the PCC
case #1	900 Kvar (head)	5	head,middle,end	Unity Power Factor	100%	No	2000	-170,-82,-158	-410
case #2	900 Kvar (head), 900 Kvar(middle)	3	head,middle	Volt-Var	3% from 1.06 to 1.09	No	2000	-170,-82	
case #2	900 Kvar (head), 900 Kvar(middle)	2	end	Volt-Var	3% from 1.06 to 1.09	No	2000	-730	-982
case #3	900 Kvar (head)	3	head, middle	Volt-Var	3% from 1.06 to 1.09	No	2000	-170,-82	
case #3	900 Kvar (head)	2	end	Volt-Var	3% from 1.06 to 1.09	No	2000	-507	-759
case #4	900 Kvar (head)	3	head, middle	Volt-Var	1% from 1.06 to 1.07	No	2000	-170,-82	
case #4	900 Kvar (head)	2	end	Volt-Var	1% from 1.06 to 1.07	No	2000	-784	-1036



- Case #4 was studied after reviewing results of Case #3.
- Case #4 has a better voltage response but still doesn't mitigate overvoltage.

Inverter Volt-Var functionality – Study (DEC System Off Peak)

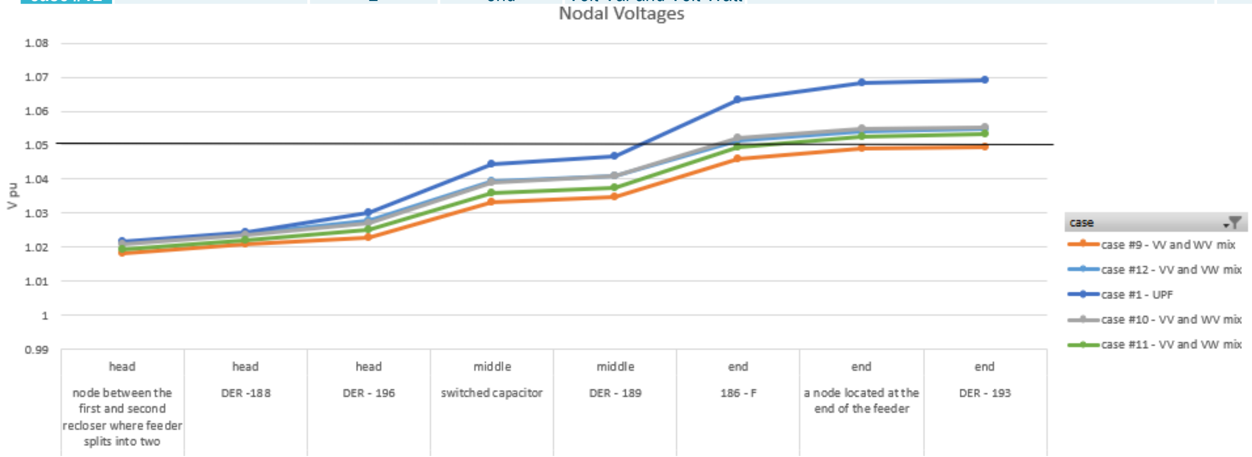
Cases	Caps	Number of DER units	Location	Control type	Control description	Gen outside 0.95 pf limit	Inverter_KW	Kvar absorption at the PCC	Total_Kvar absorption at the PCC
case #5	900 Kvar (head)	2	head	Volt-Var	3% from 1.04 to 1.07	No	2000	-170	
case #5	900 Kvar (head)	1	middle	Volt-Var	3% from 1.04 to 1.07	No	2000	-190	-1696
case #5	900 Kvar (head)	2	end	Volt-Var	3% from 1.04 to 1.07	No	2000	-1336	
case #6	900 Kvar (head)	3	head,middle	Volt-Watt	3% from 1.06 to 1.09	No	2000	-170,-82	-379
case #6	900 Kvar (head)	2	end	Volt-Watt	3% from 1.06 to 1.09	No	1793	-127	
case #7	900 Kvar (head)	5	head,middle,end	Watt-Var	P->1000 to 2000 KW and Q->0 to 968 Kvar	Yes	2000	-2162,-1079,-2150	-5391
case #8	900 Kvar (head)	2	head	Volt-Var	2% from 1.04 to 1.06	No	2000	-170	
case #8		1	middle	Volt-Var	2% from 1.04 to 1.06	No	2000	-148	-1938
case #8	900 Kvar (head)	2	end	Volt-Var	2% from 1.04 to 1.06	Yes	2000	-1620	



- Case #7 reduces voltage below 1.05 pu, but results in a significant reactive power absorption. Case #8 has a better voltage response.

Inverter Volt-Var functionality – Study (DEC System Off Peak)

Cases	Caps	Number of DER units	location	Control type	Control description	Gen outside 0.95 pf limit	Inverter_KW	Kvar absorption at the PCC	Total_KVAR absorption at the PCC
case #9	900 Kvar (head)	2	head	Volt-Var	2% from 1.04 to 1.06	No	2000	-172	
case #9		1	middle	Volt-Var	2% from 1.04 to 1.06	No	2000	-97	-2412
case #9		2	end	Watt-Var	P->1000 to 2000 KW and Q->0 to 968 Kvar	Yes	2000	-2143	
case #10	2400 Kvar (head), 900 Kvar (middle)	2	head	Volt-Var	2% from 1.04 to 1.06	No	2000	-170	
case #10		1	middle	Volt-Var	2% from 1.04 to 1.06	No	2000	-115	-2432
case #10		2	end	Watt-Var	P->1000 to 2000 KW and Q->0 to 968 Kvar	Yes	2000	-2147	
case #11	900 Kvar (head)	2	head	Volt-Var	2% from 1.04 to 1.06	No	2000	-170	
case #11		1	middle	Volt-Var	2% from 1.04 to 1.06	No	2000	-122	-1671
case #11		2	end	Volt-Var and Volt-Watt	volt-var: 2% 1.04 to 1.06 and volt-watt - 2% 1.05 to 1.07	No	1816	-1379	
case #12	1700 Kvar (head), 900 Kvar (middle)	2	head	Volt-Var	2% from 1.04 to 1.06	No	2000	-186	
case #12		1	middle	Volt-Var	2% from 1.04 to 1.06	No	2000	-195	-1929
case #12		2	end	Volt-Var and Volt-Watt	volt-var: 2% 1.04 to 1.06 and volt-watt - 2% 1.05 to 1.07	Yes	1702	-1548	



- Case #9 provides the most optimal response and reduce voltage below 1.05 pu.
- However, Case #9 has an 800 KVAR higher reactive requirement than Case #11.

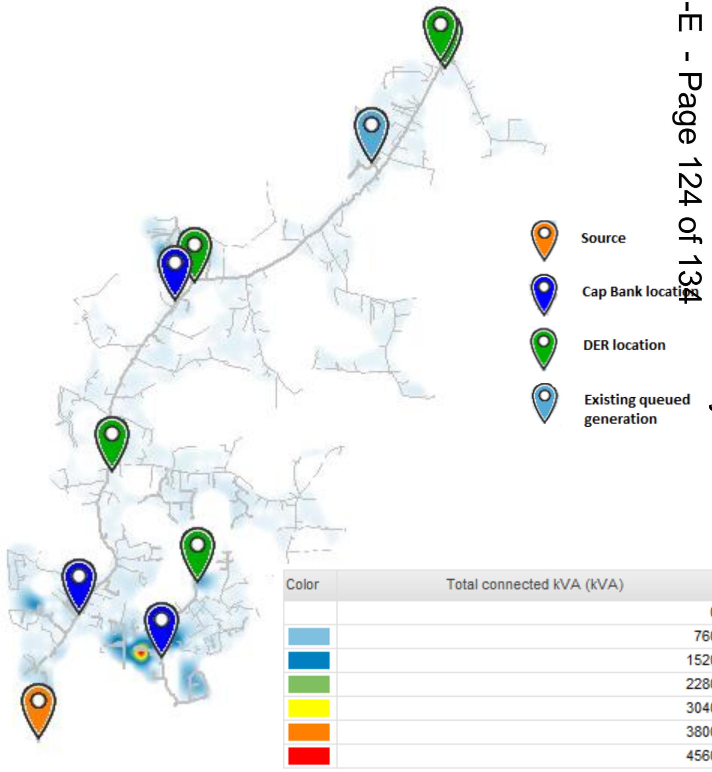
Inverter Volt-Var functionality – Study (DEC System Shoulder Peak)

- Feeder description – Feeder A shoulder peak

Feeder load characteristics	Value
Total load KW	8879.7
Total load Kvar	2105.4
load PF	97.3%
Total load KVA	9125.9
Total KVA (peak load)	13735.6
Total load as a % of peak load	66.4%

Generation*	Value
Existing queued generation (end of feeder)	336 KW
Generation with smart inverter capability modeled at the head section	4 MW
Generation with smart inverter capability modeled at the middle section	2 MW
Generation with smart inverter capability modeled at the end section	4 MW

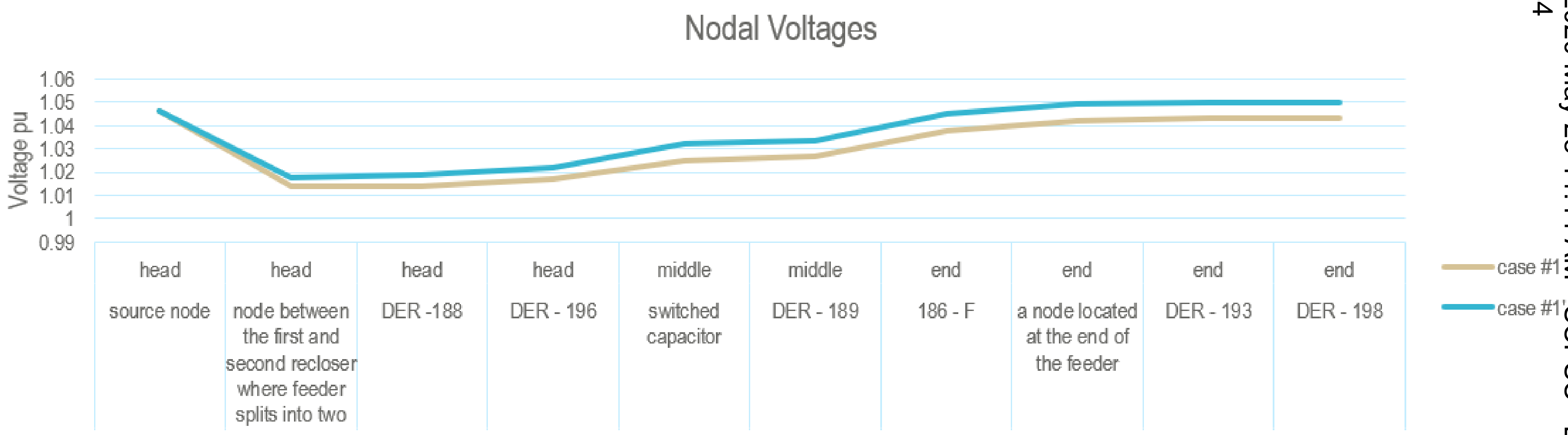
*Each 2 MW DER has a +/- 0.9 PF capability. The DER is connected to the feeder via a 0.48/23.9kV, %Z=5.75 and X/R ratio of 8.24 step up transformer.



Inverter Volt-Var Functionality – Study (DEC System Shoulder Peak)

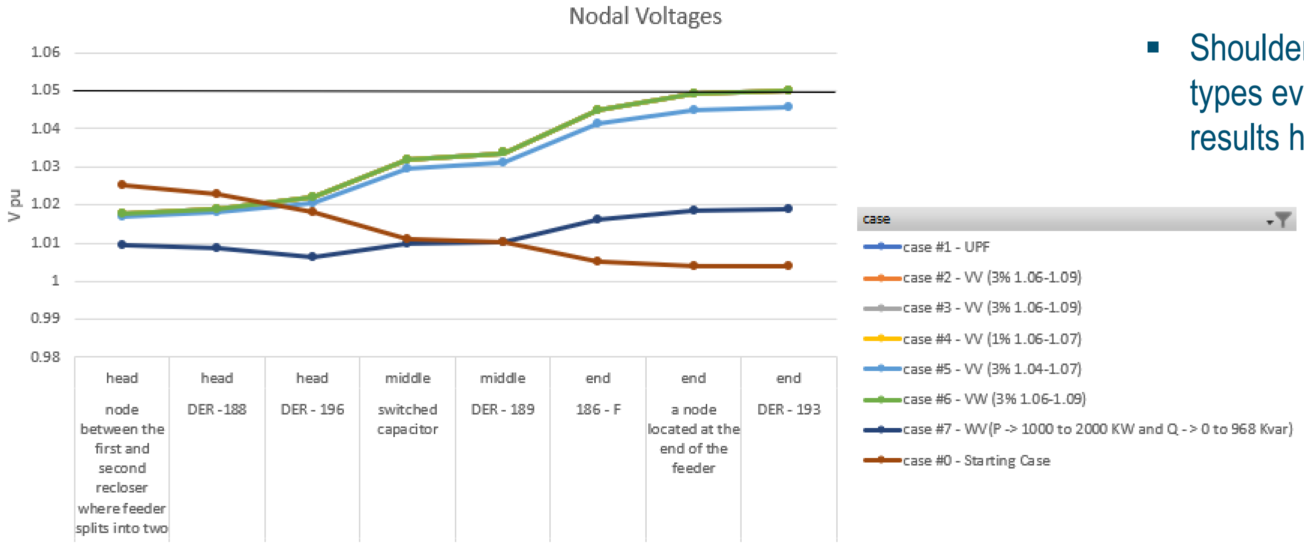
- Case Description – shoulder peak

Case	Caps	Regulator	Location	Control Type	Control Outline
case #1	offline	-5,-6,-4	head,middle and end	unity power factor	Unity power factor
case #1'	900 Kvar (head), 600 Kvar (head), 900 Kvar (middle)	-5,-6,-4	head,middle and end	unity power factor	Unity power factor



Inverter Volt-Var functionality – Study (DEC System Shoulder Peak)

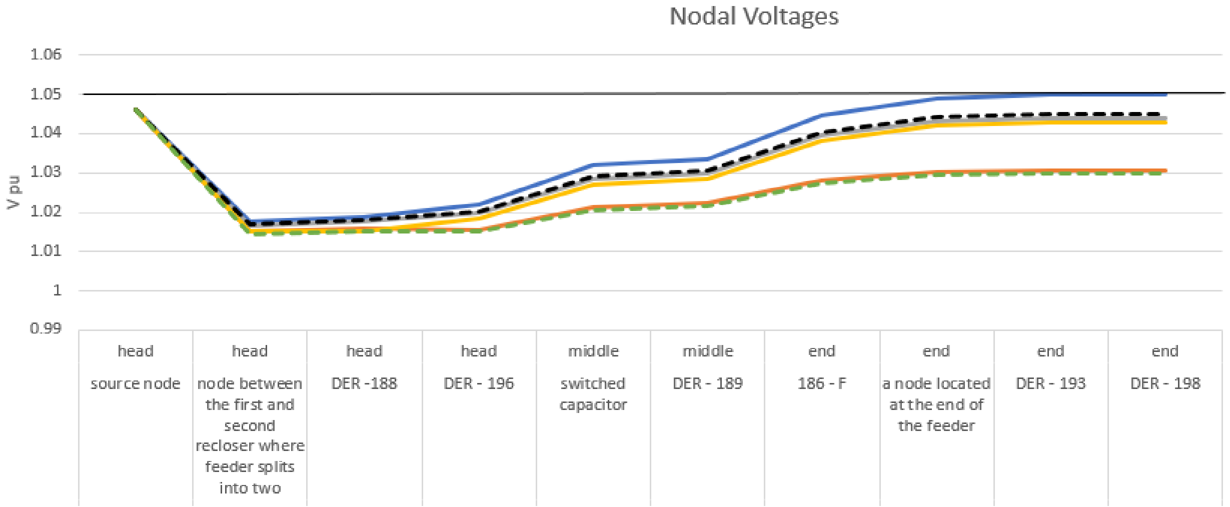
Case	Caps	Number of DER units	Location	Control type	Control description	gen outside 0.95 pf limit	Inverter_KW	Kvar absorption at the PCC	Total Kvar absorption at the PCC
case #1	1500 Kvar (head), 900 Kvar (middle)	5	head,middle,end	Unity Power Factor	100%	No	2000	-170,-82,-158	-410
case #2, #3, #4	1500 Kvar (head), 900 Kvar (middle)	3	head,middle,end	Volt-Var	3% from 1.06 to 1.09	No	2000	-170,-82,-158	-410
case #5	1500 Kvar (head), 900 Kvar (middle)	3	head,middle	Volt-Var	3% from 1.04 to 1.07	No	2000	-170,-84	-826
case #5	1500 Kvar (head), 900 Kvar (middle)	2	end	Volt-Var	3% from 1.04 to 1.07	No	2000	-572	
case #6	1500 Kvar (head), 900 Kvar (middle)	5	head,middle,end	Volt-Watt	3% from 1.06 to 1.09	No	2000	-170,-82,-158	-410
case #7	1500 Kvar (head), 900 Kvar (middle)	5	head,middle,end	Watt-Var	P->1000 to 2000 KW and Q->0 to 968 Kvar	Yes	2000	--2162,-1079,-2158	-5399

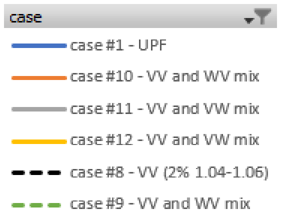


- Shoulder peak cases were tested for control types evaluated for the off-peak case to see if results hold true in the shoulder peak case

Inverter Volt-Var functionality – Study (DEC System Shoulder Peak)

Case	Caps	Number of DER units	location	Control type	Control description	Gen outside 0.95 pf limit	Inverter_KW	Kvar absorption at the PCC	Total_Kvar absorption at the PCC
case #8	1500 Kvar (head), 900 Kvar (middle)	3	head,middle	Volt-Var	2% from 1.04 to 1.06	No	2000	-170,-148	-978
case #8	1500 Kvar (head), 900 Kvar (middle)	2	end	Volt-Var	2% from 1.04 to 1.06	No	2000	-660	
case #9	1500 Kvar (head), 900 Kvar (middle)	3	head,middle	Volt-Var	2% from 1.04 to 1.06	No	2000	-172,-86	-2412
case #9	1500 Kvar (head), 900 Kvar (middle)	2	end	Watt-Var	P->1000 to 2000 KW and Q->0 to 968 Kvar	Yes	2000	-2154	
case #10	3900 Kvar (head), 900 (middle)	3	head,middle	Volt-Var	2% from 1.04 to 1.06	No	2000	-172,-86	-2412
case #10	3900 Kvar (head), 900 (middle)	2	end	Watt-Var	P->1000 to 2000 KW and Q->0 to 968 Kvar	Yes	2000	-2154	
case #11	1500 Kvar (head), 900 Kvar (middle)	3	head,middle	Volt-Var	2% from 1.04 to 1.06	No	2000	-170,-148	-978
case #11	1500 Kvar (head), 900 Kvar (middle)	2	end	Volt-Var and Volt-Watt	volt-var: 2% 1.04 to 1.06 and volt-watt - 2% 1.05 to 1.07	No	2000	-660	
case #12	2500 Kvar (head), 900 (middle)	3	head,middle	Volt-Var	2% from 1.04 to 1.06	No	2000	-170,148	-1030
case #12	2500 Kvar (head), 900 (middle)	2	end	Volt-Var and Volt-Watt	volt-var: 2% 1.04 to 1.06 and volt-watt - 2% 1.05 to 1.07	No	2000	-712	





- The results indicate, control setpoint picked for off-peak would work for shoulder-peak as well.
- The reactive compensation is also set by the off-peak case

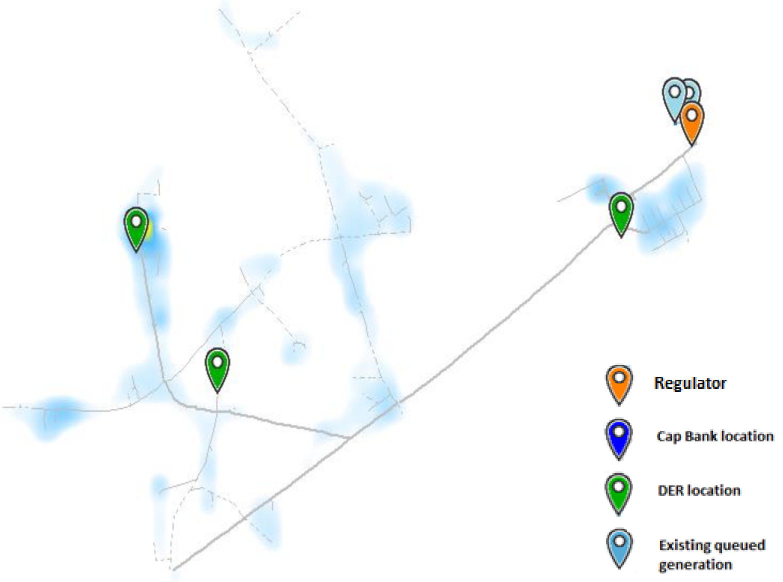
Inverter Volt-Var functionality - Study (DEP System Off-Peak)

- Feeder B description – off-peak

Feeder load characteristics	Value
Total load KW	252.2
Total load Kvar	94.7
load PF	94.0%
Total load KVA	269.4
Total KVA (peak load)	7103.8
Total load as a % of peak load	3.8%

Generation*	Value
Existing queued generation (head of the feeder)	10 MW
Generation with smart inverter capability modeled at the head section	2 MW
Generation with smart inverter capability modeled at the middle section	2 MW
Generation with smart inverter capability modeled at the end section	2 MW

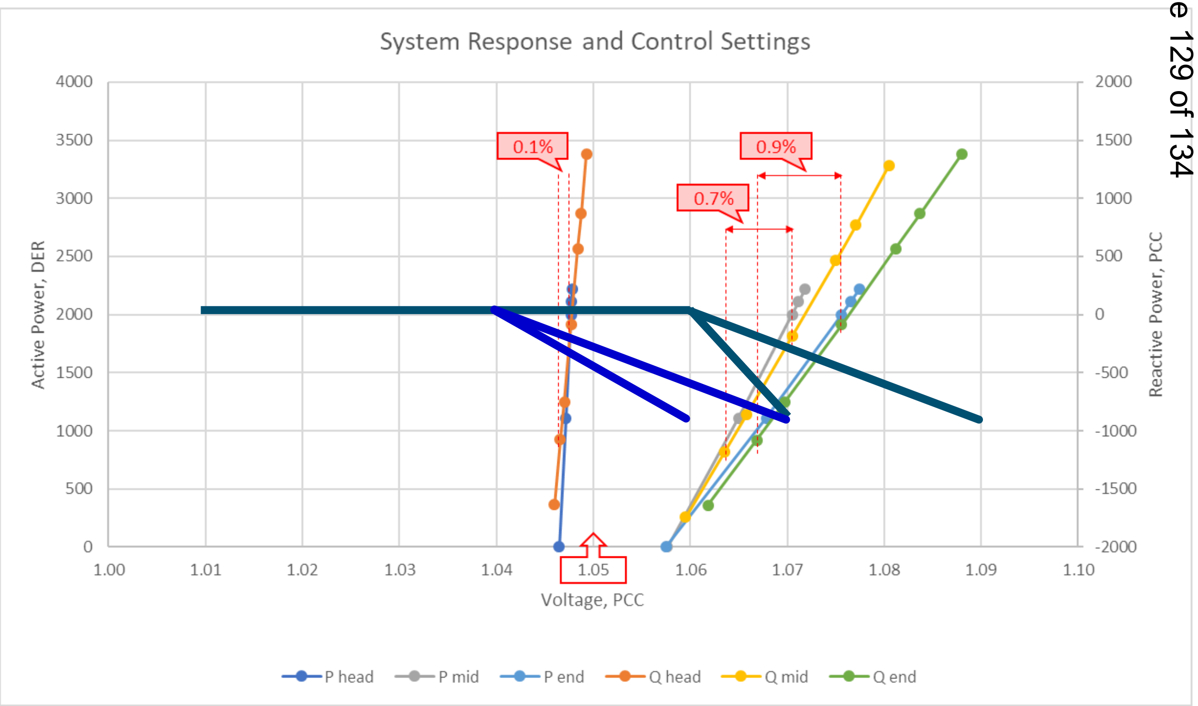
*Each 2 MW DER has a +/- 0.9 PF capability. The DER is connected to the feeder via a 0.48/23.9kV, %Z=5.75 and X/R ratio of 8.24 step up transformer.



Color	Total connected kVA (kVA)
	0.0
Blue	178.3
Yellow	356.7
Red	535.0

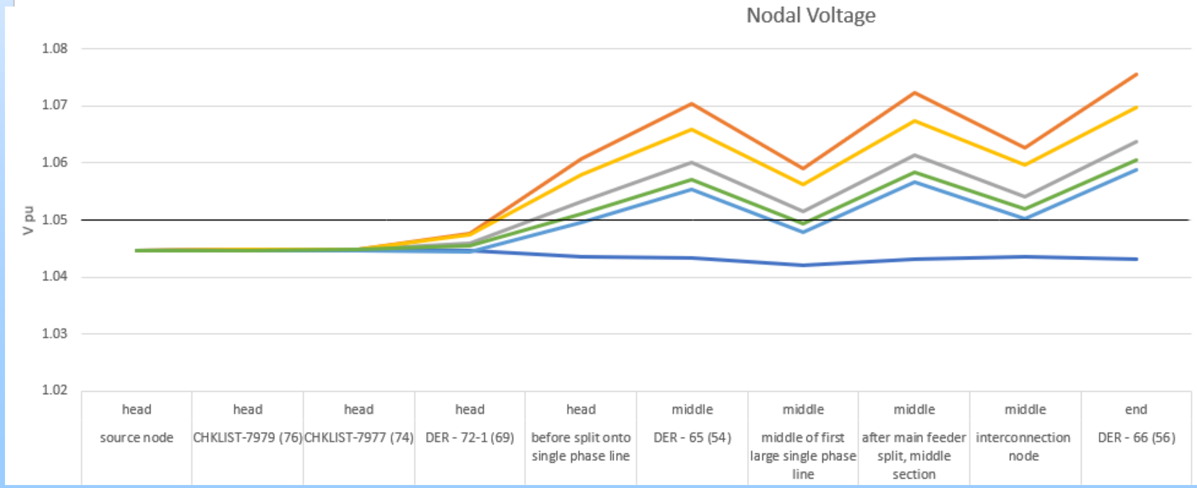
Application to Settings

- The response at the end of the feeder is similar to the previous circuit
- The response at the head is much lower
- The last two controllers are electrically close, that indicates similar controls should be effective
- Given the voltage at the head, the first DER is likely to operate absorbing
- The last two DER are expected to operate near reactive limit

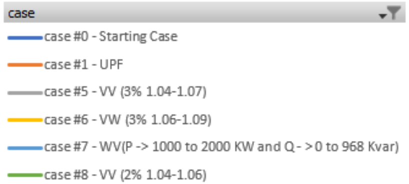


Inverter Volt-Var functionality – Study (DEP System Off-Peak)

Case	Caps	Number of DER units	Location	Control type	control outline	gen outside 0.95 pf limit	Inverter_KW	Kvar absorption at the PCC	total Kvar
case #1	none	3	head,middle,end	Unity Power Factor	Unity Power Factor	No	2000	-82,-78,-86	-246
case #5	none	1	head	volt-var	3% from 1.04 to 1.07	No	2000	-276	
case #5	none	1	middle	volt-var	3% from 1.04 to 1.07	No	1999	-744	-1897
case #5	none	1	end	volt-var	3% from 1.04 to 1.07	Yes	1999	-877	
case #6	none	1	head	volt-watt	3% from 1.06 to 1.09	No	2000	-82	
case #6	none	1	middle	volt-watt	3% from 1.06 to 1.09	No	1769	-63	-198
case #6	none	1	end	volt-watt	3% from 1.06 to 1.09	No	1490	-53	
case #7	none	3	head,middle,end	watt-var	P_1000->2000kW Q_0-928kVAR or 0.9 pf	Yes	2000	-1075,-1072,-1078	-3225
case #8	none	1	head	volt-var	2% from 1.04 to 1.06	No	2000	-347	
case #8	none	1	middle	volt-var	2% from 1.04 to 1.06	Yes	1999	-923	-2341
case #8	none	1	end	volt-var	2% from 1.04 to 1.06	Yes	1999	-1071	

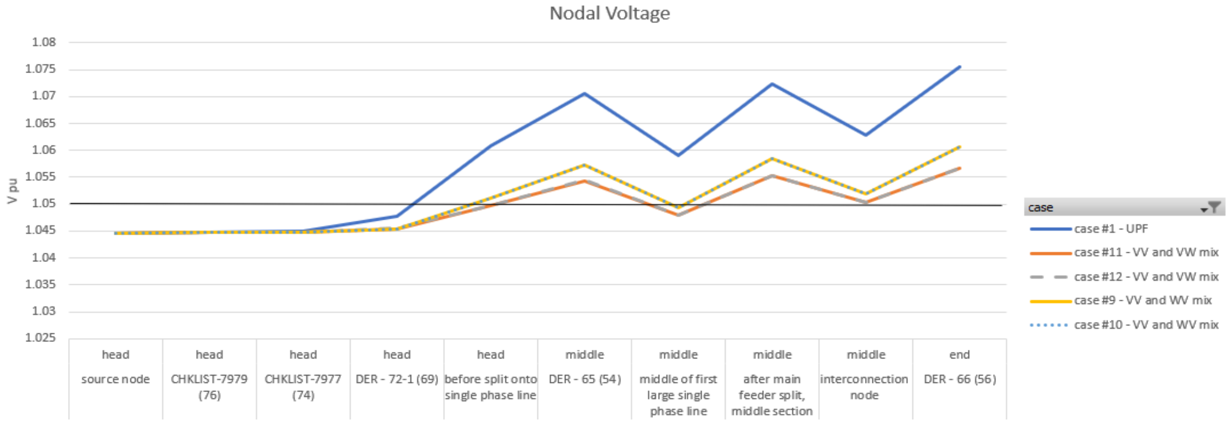


- Control setpoints evaluated for Feeder A were also evaluated for Feeder B. As expected, Case #7 reduces voltages the most but has a very high reactive power absorption. Case #8 has a better response.



Inverter Volt-Var functionality – Study (DEP System Off-Peak)

Case	Caps	Number of DER units	Location	control type	control outline	gen outside 0.95 pf limit	Inverter_KW	Kvar absorption at the PCC	total Kvar
case #9	none	1	head	volt-var	2% from 1.04 to 1.06	No	2000	-346	-2341
case #9	none	1	middle	volt-var	2% from 1.04 to 1.06	Yes	1999	-923	
case #9	none	1	end	watt-var	P_1000->2000kW Q_0-928kVAR or 0.9 pf	Yes	1999	-1072	
case #10	2400 Kvar (head)	1	head	volt-var	2% from 1.04 to 1.06	No	2000	-346	-2341
case #10	2400 Kvar (head)	1	middle	volt-var	2% from 1.04 to 1.06	Yes	1999	-923	
case #10	2400 Kvar (head)	1	end	watt-var	P_1000->2000kW Q_0-928kVAR or 0.9 pf	Yes	1999	-1072	
case #11	none	1	head	volt-var and volt-watt	volt-var: 2% from 1.04 to 1.06 and volt-watt - 2% from 1.05 to 1.07	No	2000	-352	-1934
case #11	none	1	middle	volt-var and volt-watt	volt-var: 2% from 1.04 to 1.06 and volt-watt - 2% from 1.05 to 1.07	Yes	1679	-752	
case #11	none	1	end	volt-var and volt-watt	volt-var: 2% from 1.04 to 1.06 and volt-watt - 2% from 1.05 to 1.07	Yes	1449	-830	
case #12	2000 Kvar (head)	1	head	volt-var and volt-watt	volt-var: 2% from 1.04 to 1.06 and volt-watt - 2% from 1.05 to 1.07	No	2000	-352	-1934
case #12	2000 Kvar (head)	1	middle	volt-var and volt-watt	volt-var: 2% from 1.04 to 1.06 and volt-watt - 2% from 1.05 to 1.07	Yes	1679	-752	
case #12	2000 Kvar (head)	1	end	volt-var and volt-watt	volt-var: 2% from 1.04 to 1.06 and volt-watt - 2% from 1.05 to 1.07	Yes	1449	-830	



- Case #9 and Case #11 have better voltage responses. Case #11 reduces active power, whereas Case#9 results in an additional 400 KVAR reactive power absorption as compared to Case #11.

Inverter Volt-Var functionality

- Summary of Results:
  - The control settings evaluated for Feeder A were also evaluated for Feeder B.
  - Study indicates a standalone volt-var controller is not sufficient to mitigate voltage issues for DER units at the end of the feeder. dP/dV and dQ/dV curves confirm this result as well.
  - dP/dV and dQ/dV curves also indicate limited voltage control would be available for units at the head of the feeder.
  - Volt-Var control in combination with Volt-Watt control or a standalone Watt-Var controller could work for units at the end of the feeder.
  - Universal controller could work:
    - Best controller for Feeder A off-peak would also work for Feeder A shoulder-peak and other loading conditions.
    - The same controller for Feeder A could work for Feeder B. Studies on additional feeders would give an indication on this.

Inverter Volt-Var functionality – Next Steps

- Incorporate stakeholder feedback into these first 2 feeders
- Set up the testing parameters for the remaining 4 feeders.
- Apply dV/dP and dV/dQ calculations in determining appropriate control methodology and control settings.
- For the optimized control settings determine approximate Var compensation magnitude and suggested source/equipment on high-level (if any needed) to maintain the power factor (or reactive power) at the feeder and bank level.
  - Provide reactive compensation equal to the reactive power absorbed at the DER PCC
- Evaluate if a universal controller is effective for all the circuits.
- Set the long-term dynamic profiles with the identified load and irradiance profiles and simulate test days with the optimized control settings.

Stakeholder Name	Page Number	Paragraph/ Line Number	Comment	Proposed Change